Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia e il Continente Organismo di Diritto Pubblico
(Legge n° 1158 del 17 dicembre 1971, modificata dal D.Lgs. n°114 del 24 aprile 2003)

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.
IMPREGILO S.p.A. (MANDATARIA)
SOCIETÀ ITALIANA PER CONDOTTE D'ACQUA S.p.A. (MANDANTE)
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Unità Funzionale	OPERA DI ATTRAVERSAMENTO	PG0023_F0
Tipo di sistema	ATTIVITA' DI CARATTERE GENERALE	
Raggruppamento di opere/attività	ELEMENTI DA CARATTERE GENERALE	
Opera - tratto d'opera - parte d'opera	Design Basis	
Titolo del documento	Design Basis - Mechanical and Electrical, Annex	

CODICE: C G 1 0 0 0 P R G D P G E 0 0 0 0 0 0 0 0 0 0 0 1 F0

REV	DATA	DESCRIZIONE	REDATTO	VERIFICATO	APPROVATO
F0	20/06/2011	EMISSIONE FINALE	CFA, PVN, ABR	CFA	MES/EYA

NOME DEL FILE: PG0023_F0

INDICE

Abbreviations

ASTM	American Society for Testing and Materials
BAN	Bridge Area Network
Bridge	Messina Strait Bridge
BS	British Standard
CCTV	Closed Circuit TeleVision
CEI	Comitato Elettrotecnico Italiano
EMC	Electro Magnetic Compatibility (Compatibilità elettromagnetica)
EN	European Standard
ENEL	Italian Electrical Power Utility
GBIC	Gigabit Interface Converter
General Contractor	Eurolink
HV	High Voltage
IEC	International Electrotechnical Commission (Commissione Elettrotecnica Internazionale - CEI)
LAN	Local Area Network
LPS	Lightning Protection System (Sistema di protezione contro i fulmini)
LV	Low Voltage
MDIX	Medium Dependent Interface
NIC	Network Interface Controller
PBX	Private Branche eXchange
PE	Protective earthing (Conduttore di protezione)
PDS	Premises Distribution System
PSTN	Public Switched Telephone Network
SCADA	Supervisory Control and Data Acquisition system

SILS	Serviceability level of the Bridge: Extreme accidental and environmental loading conditions
SLS 1 and 2	Serviceability level of the Bridge (Normal use)
TETRA	TErrestrial Trunked RAdio
TNS	Earthing system with separate neutral and protective conductors
UNI	Ente Nazionale Italiano di Unificazione
UPS	Uninterruptible Power Supply
VLAN	Virtual Local Area Network
VoIP	Voice Over internet Protocol
WAN	Wide Area Network

1 Executive Summary

1.1 Introduction

This document is the executive summary for the report: “Design Basis, Mechanical and Electrical” document number CG.10.00-P-RG-D-P-IT-M2-00-00-00-00-01-0.

The Design Basis identifies the scope of work to be performed under the contract and the electrical and mechanical characteristics the technical installations must fulfil. The aim of the Design Basis is to establish the basic requirements to ensure a reliable and safe operation of the bridge.

- The E&M design work covers the main bridge between eastern viaduct bridge and western viaduct bridge. The bridge has a dual carriageway road with two lanes and an emergency lane in each direction and a dual railway track in the middle section of the bridge.

The railway installations and all E&M installations outside the Main Bridge are not covered by the design basis.

The Design Basis is based on the contractual documents issued by Stretto di Messina S.p.A.

1.2 Aim of the Design Basis

The Design Basis establishes the basic requirements of the technical installations. The aim to ensure a reliable and safe operation of the bridge with only few limitations to the design principles..

1.3 Technical Installations

1.3.1 Traffic Management System (Roads)

The objective of the traffic managemeny system is to:

- to manage the traffic flow according to changing actual traffic, road, structural- and meteorological conditions achieving efficient and safe passage for road vehicles on the bridge.

- to provide a predictions basis for continuous provision of traffic data for traffic analysis purposes - primarily traffic statistical purposes and simulation of extreme situations for training purposes.

1.3.2 Electric Power Supply System

The power supply and distribution works cover establishing of reliable power supply and distribution system providing power to the installations on the bridge. The normal power supply shall be connected through main power supply substations to the local ENEL grids on both sides of the bridge, respectively in Calabria and Sicily. Emergency generators located in these main power supply substations and Uninterruptable power supplies must maintain power on selected safety systems during a fault on the main power supplies. The UPS must maintain the power supply to the equipment which do not accept a power cut or where a power cut is unacceptable for safety reasons. The UPS must maintain power for these loads for a minimum time of 30 minutes or higher if required for any safety reasons.

1.3.3 Communication Systems

The communication systems works cover establishing of reliable communications network for the management of the Operation and Maintenance of the Bridge.

The communications networks shall include:

- Data communications network based on Ethernet with backbone of redundant optical fibre rings.
- Radio communication network based on TETRA technology covering the Bridge, outside and inside the girders.
- Telephone system based on VoIP.
- Emergency telephones (SOS Colonnine) along the roads.

Police, Rescue and other emergency services have their own radio communication systems and their respective technical organisations shall provide the necessary radio coverage.

The communications systems shall be designed using state of the art digital technology in order to ensure flexibility and maximum lifetime of the equipment.

1.3.4 Control and Monitoring Systems

The system for operation of the bridge shall be designed to support real-time monitoring and management of the road and railway traffic and provide sufficient means for management of bridge maintenance and preparation of analysis and detection of risks in case of extreme weather or/and traffic conditions, for the fire prevention and alarm.

The bridge management and control system shall be interconnected with installations for all approaching parts of the traffic system.

This data input is not limited to daily operation events only, but shall focus also on short term and long term prediction of traffic volumes, maintenance needs and optimization of interventions in case of traffic restrictions due to weather conditions, special transports, traffic accidents and safety threats.

1.3.5 Lighting Systems

The Design Basis requires lighting installations on the bridge.

- Road lighting (including maintenance and operation lanes).
- Architectural lighting for Towers and Suspension System, including Deck
- Sea and air traffic lights
- Internal lighting

Lighting shall be installed in the internal volumes (bridge deck, towers, crossing beams, anchor blocks etc.) to allow operation, inspection and maintenance activities.

1.3.5.1 Road Lighting

The road lighting system shall be based on luminaires with LED lamps, to provide long maintenance intervals.

The road lighting systems shall be automatically controlled by the SCADA system. Reduction of the lighting level during hours of low traffic intensity shall be provided.

The daytime appearance of the road lighting installations shall be closely coordinated with the landscaping and architectural features of the bridges during the detailed design phase.

There shall be two luminaires on each pole in order to secure high redundancy of the system.

1.3.5.2 Architectural lighting

The towers and cross beams shall be illuminated by means of a architectural lighting. The ratio between the luminance of the lighted surface and the environment luminance shall be 30/50 - 1. The classical lighting may be based on metal halide floodlights.

The illumination shall provide a pleasant and uniform luminance of the surfaces of the bridge structures. The luminance level shall be kept low, approximately 2-10 cd/m^2.

Cables and hangers shall be lighted by LED lights, or combination of LED lights and conventional lights.

In order to complete the visual night time impression of the Bridge, and to outline the structure for the sea traffic, the underside of the bridge girder shall be illuminated also.

1.3.5.3 Navigation Warning Lights

The General Contractor shall design and install the lighting system of the Bridge and the Straight accordingly to the applicable rules, standards and requirements provided by the Marine Authority (i.e. COMANDO ZONA FARI – " MARIFARI MESSINA").

Red and green leading lights, white range lights and alignment lights will equipped with long-life, extra-low voltage incandescent lamps in automatic lamp changers containing up to 6 lamps.

The effective range of the lights shall be 7.5 - 10 nm.

The operation will be monitored by current sensors, and will, together with "Last lamp in use" be signalled to the CMS/SCADA system.

1.3.5.4 Aircraft Warning Lights

This system shall be designed accordingly to the ICAO, International Civil Aviation Organization, (Annex 14 – Volume 1° - chapter 4°) and “Regulation for the airport construction and operation”- ENAC, OAC, NIKAO standards.

White, flashing aviation warning lights of high intensity shall be located at the top of the towers and at the lowest point of the catenery.

The lamps shall be omnidirectional and double type; the intensity of the light emission (white), shall be adjustable.

The warning lights shall be divided into two equal subsystems, each system covering one tower and a half of the bridge. The feeding of the mentioned switchgears shall be continuous and the inverters shall have at least 3 hours back-up.

Aeronautical obstacle lighting for the towers shall be high intensity flashing white lights mounted for full visibility from all bearings. The intensity will be automatically adjusted by photocell control / CMS/SCADA in accordance with the background lighting (full sun, twilight or night).

Aeronautical marking of the cable stays - if required - shall be medium intensity red lights, flashing or fixed, pending further investigations and clarification of the requirements of the authorities.

1.3.5.5 Internal lighting and power

Internal lighting shall be installed in the external areas and in the internal volumes (bridge deck, towers, crossing beams, anchor blocks etc.) to allow operation, inspection and maintenance activities.

This lighting system shall be supplied from an uninterruptible power supply (UPS) to allow evacuation and increase safety in case of power supply failures.

All the maintenance and inspection routes shall be provided with power sockets (at intervals of 30 meters) for tools or auxiliary lamps connection.

1.3.6 Safety Systems

The Bridge shall be equipped with an efficient system for safety related monitoring of all suspicious events related to the road/railway traffic and events in approach areas to Bridge on land, air and surrounding waters.

The Safety Systems (SSS) shall comprise of supply and installation of one or more computerised surveillance systems which are developed for protection of the Bridge against intrusion, sabotage and terrorism. The system contains of the following sub-systems:

- Anti-intrusion system.
- Anti-sabotage system.
- Anti-terrorism system.

1.3.7 Lightning Protection and Earthing

Lightning protection system and earthing facilities shall be provided for the protection of the installations on the bridge, as well as bridge structures. The lightning protection system shall comply with CEI EN 62305.

The lightning protection of following structural elements shall be designed:

1. Lightning protection of towers.
2. Lightning protection of anchor blocks.
3. Lightning protection and earthing of the bridge deck.
4. Equipotential bonding of all steel constructions and elements of the bridge.

The steel construction of the tower forms a natural air termination and down conductor.

The reinforcement of tower foundations shall be interconnected in order to provide sufficiently low earthing system for the tower. The tower shall be electrically connected to the foundation earthing system.

The reinforcement of terminal piers shall be interconnected in order to provide sufficiently low earthing system.

The bridge deck shall be electrically connected to the earthing system in tower foundations and terminal piers.

The reinforcement of anchor blocks shall be interconnected in order to provide sufficiently low earthing system for the bridge cable lightning protection and earthing system for the M&E installations in the achor blocks.

All electrical and mechanical systems shall be earthed or bonded in accordance to the standards.

1.3.8 Monitoring of Structures

The Structural Health Monitoring System (SHMS) shall be a sophisticated redundant set-up that shall provide the owner and operator with important information concerning structural behaviour and safety as well as information that will assist with operation and maintenance planning. The SHMS will also provide a valuable tool for investigating and trouble-shooting unforeseen problematic behaviour such as wind induced vibrations.

1.3.9 Water Distribution and Fire Fighting

This system shall be designed for the pressurized water distribution for the following purposes:

- Fire fighting on bridge and towers (Fire hydrant system).
- Washing system for steel structures.

The water and fire distribution main on bridge are placed on both sides of the railway girder.

The fire mains are connected to fire hydrants located with a distance inferior of 60 m. The fire hydrants will be accessible from the roads.

In the towers will fire hydrants be located at the base and in each cross beam.

Fire hydrants for bridge will be for 1,000 l/min at 6,9 bar. Fire hydrants for towers will be for 300 l/min at 4 bar.

Water for washing of steel structures shall be from flush valves connected to the pipe mains. Valves shall be for connection to mobile washing tanks located on the maintenance gantries.

1.3.10 Drainage

The purpose of the drainage system is to collect polluted first flush water from the bridge and treat it at land based facilities before discharge to the sea.

Drainage from the bridge shall be achieved by gravity.

2 Introduction

2.1 Stretto di Messina Link

The characteristics and overall scope of the Permanent Works under this Contract are outlined as follows:

- The limits for these E&M design works cover main bridge only and are limited to the part of the bridge between the eastern viaduct bridge and western viaduct bridge.
- A dual carriageway road on the bridge with two lanes in each direction and emergency lanes.
- A dual railway track in the middle section of the bridge.

The design of E&M systems outside the Main Bridge will be covered by separate design package prepared by the General Contractor at later stage. The design works to be continued at the later stage of the projects are defined in section 1.3.

2.2 Basis Documents

This Design Basis is based on the contractual documents issued by the Owner, Stretto di Messina S.p.A.

A list of contractual documents covering the “Definitivo” and “Esecutivo” design for the Stretto di Messina Bridge is included in Appendix 1.

2.3 Electrical and Mechanical (E&M) Installations and Systems on the Bridge

The E&M installations and systems shall guarantee reliable operation and safety of the bridge. They consist of common systems and bridge installations and systems.

2.3.1 Common Systems

The common systems are not related to any definite geographic location at the bridge. The common systems for the Stretto di Messina Link are:

- Traffic management system (roads).

- Redundant electric power supply system.
- Telecommunication system ensuring data transmission and telephone communication.
- Control and Monitoring systems.

2.3.2 Bridge Installations and Systems

The bridge installations and systems shall include:

- External lighting systems
- Interior lighting
- Safety systems (anti-sabotage, railway traffic monitoring and bridge access control, fire detection)
- Lightning protection and earthing
- Electrical distribution system for LV power supply of mechanical and electrical systems
- Telecommunication systems (Telephones, emergency telephones)
- Monitoring of structures
- Dehumidification
- Hydraulic Buffers
- Fire fighting
- Water distribution
- Drainage
- Ducting for electrical cabling
- Inspection and access facilities.

3 General Design Requirements

3.1 Priority of Codes and Standards

The priority of codes and standards shall be in accordance with following sequence:

1 Italian acts in force

2 Document G.C.G.F.04.01

3 UNI EN (National Italian Standards) and CEI

4 Euronorm (EN, CENELEC)

5 BS-ASTM.

The most applicable standards are shown in Appendix 2.

3.2 Environmental conditions

The Environmental and Loads Conditions to be considered during the design are those specified in the document GCG.F.04.01 “Design Basis and Performances required for the Bridge” and GCG.F.05.03 “10.9.4.1 Parametri progettuali di base”. However the following further parameters shall also be considered:

Table 3.1 Climatic conditions for electrical and mechanical equipment, installations and systems

Max Relative Air humidity	100%
Min. Environmental Temperature at the sea level	-2 °C
Max. Environmental Temperature at the sea level	+ 43°C
Max Level of instantaneous rainfall	This to be understod as the designrain with a return period of 100 years. To identified during detailed design
Rain per month	51-160 mm
Condensation	Yes
Salt-fog	Yes
Max wind speed (as per CEI 11-17)	180 km/h
Level of wind velocity corresponding to serviceability limit SLIS	60 m/s
Level of wind velocity corresponding to serviceability limit SLS2. Occurrence: every 200 years	47 m/s
Prevailing Wind Direction	NW-S
Seismicity	as per applicable regulations and table 2.3 below
Lightnings	1,5-2,5 number/year/km2

3.3 Seismic Conditions

Table 3.2 Seismic conditions for electrical and mechanical equipment, installations and systems

Seismic factor	Magnitude	Unit	Reference document
Earthquake, max severity	M=7.1	Richter	Ref.: PP 2R B0 001/2.5.1
Earthquake, acceleration corresponding to serviceability limit SILS	6.3	m/s^2	Ref.: PP 2R B0 001/2.5.1
Earthquake, acceleration corresponding to serviceability limit SLS2 Occurrence: every 200 years	2.6	m/s^2	
Tsunami, withstand	-	-	Any instrumentation equipment (sensors) that has interface to the sea. Ref.: Doc. no. PP 2R A 22/2.5.1
Tsunami, warning	-	-	Warning system will be proposed by others. Ref.: Doc. no. G.C.G.F.05.03 page 362 of part 2.

3.4 System of Units

The International System of Units (metric system) as specified in IEC or BS 5555 shall be used throughout the Contract.

3.5 Design life

The design life L_d of the bridge is 200 years.

The design life of E&M installations is shorter than 200 years due to technological development in this field and need for continuous upgrading of these systems in order to follow up on new technical developments. For electrical and mechanical installations a maintenance plan must be prepared and this plan shall include periodical replacements of the components and/or whole systems.

The minimum design life for M&E components shall comply with the requirements defined in Appendix 3.

3.6 Safety

All the materials and the equipment shall be designed and manufactured to insure safety to the personnel and machinery also in case of failure of the electrical or hydraulic network and related control and regulation systems.

The height and the size of the areas to be used by the personnel shall be designed as per applicable standards to meet all the required safety conditions.

All the electrical components shall be fire retardant, no toxic and zero smoke.

Dangers or any kind of risk shall be outlined by using signage as per applicable regulation. All warning text shall be in Italian language.

All the material and equipment shall be provided with all the necessary safety devices to allow the correct use and maintenance (i.e. locks, earthing, etc…).

The General Contractor shall make sure that all the plants shall be designed in order to avoid failures, breaks down, etc…which can affect the whole safety level and the traffic safety.

Furthermore he must guarantee a very high safety standard to passengers and personnel both in normal and emergency conditions.

3.7 Operation

All the components shall have an identification tag carrying the main data of the project and the main identification parameter of the component itself.

All the apparatus, such as breakers, regulators, actuators, shall be provided with a positioning indicator to allow immediate knowledge of its status.

The plants control devices shall be easily accessed.

All the measuring and indication devices shall be orientated in order to facilitate the data reading.

The technological plant of the Bridge shall be designed in order to allow:

- Centralized tele-monitoring and tele-management of the plants. The Operating Center shall be located in the “Centro Direzionale”.
- Local control and management of the equipment and plants.
- Recording of the events and critical status’ during the functioning period, to optimise itself and facilitate the RCM activity.
- Automatic management of the routine working conditions and, in case of emergency, of the proper automatic procedure. (The local and manual management system shall be allowed as well as the centralized one).

3.8 Inspection and Maintenance

All the components shall be designed in order to facilitate the inspection and mounting/dismounting operations for maintenance and repairing/replacement purposes.

Furthermore all the electromechanical installation shall not interfere with the maintenance activities of the main infrastructures.

Unless in very exceptional and approved cases, the mounting and dismounting activities shall not require operations on the civil infrastructures or plant blocks.

These activities shall be simplified so that no high skilled or specialized personnel shall be required jointly to special tools other than those supplied within the contract.

The components shall be designed to reduce the risk of liquid contamination during the dismounting or in general disassembly activities. Controlled liquid discharge and collection facilities shall be provided.

The worn parts shall be designed to be easily replaced.

All the main components shall be provided with lifting accessories (hooks, lifting lugs, etc) to facilitate handling and transport.

The supplies shall also include monorails, hoists, etc.

All the necessary details and auxiliaries' civil structures or accessories to allow the mounting and dismounting activities shall be shown on the lay out drawings, and design drawing details.

3.9 Operational an Personal Safety

The safe operation of electrical and mechanical systems shall be ensured under normal conditions and in case of failure conditions.

The systems shall be dimensioned to ensure CF (Complete Functionality) of the bridge in case of failures such as failure in part of electrical power supply system or failure in the water supply system. At CF the operation of railway and road shall be guaranteed.

The systems shall ensure safe operation of the bridge in case of lack of adequate natural illumination.

The systems of protection of personal safety in connection with the operation and maintenance shall be designed according to Italian laws and directives in force. Provisions shall be made to ensure easy access and adequate level of safety during inspections and maintenance operations.

3.10 Electromagnetic Compatibility

The electrical and mechanical apparatus and equipment shall comply with EMC directive 89/336/ECC with later changes.

The equipment shall be CE marked.

For each type of equipment the harmonized EMC product- or generic standard shall be stated, including the test levels for emission of electromagnetic interference and immunity against the interference.

The EMC Plan in table below shall be followed.

Table 3.3 EMC Plan

No.	Description
1	**Basis for EMC requirements** -EMC-Directive -Italian EMC legislation -Specific contractual EMC requirements in doc. no. G.C.G.03.05
2	**Formal requirements** The conformity declaration for CE marking for all delivered equipment shall be provided.
3	**EMC environment at the bridge** The equipment shall function correctly in following EMC environment: 3.1 Environment, where there occur electromagnetic disturbances: Large fault currents, lightning currents, switching currents, induced voltages and overvoltages originating from: -HV substations and switchgears- -HV substations and switchgears -Railway installations. 3.2 Environment, where small currents or voltages are transmitted: -Instruments and sensors -PC -Railway signalling systems -Electronic equipment
4	**Immunity and emission requirements** -The electromagnetic emission and immunity of apparatus, complex components, installations and systems shall comply with the limit values specified in the relevant harmonized EN product standard.

	-Where a product standard is not available generic standard in force for the EMC environment specified in section 3 above shall be used. -Test levels shall correspond to EMC environments specified in section 3 above.

3.11 Vibration Resistance

The equipment shall function correctly under vibrations of the bridge structures induced by:

- Railways: about 200 trains a day
- Road traffic: about 140,000 cars a day
- High wind velocities.

The equipment shall withstand earthquake vibrations and shock of the bridge structures.

3.12 Standardization and inter-changeability

All the components shall be interchangeable for the following, as minimum:

- Homologous pieces of materials and identical apparatus.
- Similar Accessories of different systems: i.e. electrical motors, pumps, Valves, electrical devices, etc.

The General Contractor shall standardize as much as possible the work execution in order to reduce the necessary spare parts.

The main data, tolerances, etc. to define the inter-changeability of the pieces shall be included in the drawings.

3.13 Operation Costs

All the systems and components, shall be designed to minimize the operation costs, energy demand satisfying the LCC requirements described in the Document GCG.F.06.02 " RMC Studies and LCC Studies ".

3.14 Mechanical Stress

Particular care shall be taken to reduce the mechanical stresses due, for example, to vibrations, structural deformations, thermal expansions etc.

The General Contractor shall make sure that all the elements, like cables, cable trays, piping, etc, shall be free from the mechanical stresses, vibrations, etc. associated to the primary structures and vice-versa.

The following guideline shall be followed since the beginning of the design phases:

- The measurement, security devices, actuators, etc. shall be installed and protected by vibrations by using shock absorbers, independent supports).
- The plants shall be provided with expansion joints, where necessary, in order to ensure structural elasticity. All the elastic connections, expansion devices etc. shall be designed in order to guarantee the integrity of all the strength, process continuity, isolation, tightness characteristics, etc.

Fatigue effect shall be avoided.

Sleeves for pipes, cables, etc. shall be foreseen to cross walls or diaphragms and to guarantee mechanical protection and /or, whenever required, liquid or gas tightness. Particular care shall be taken wherever fire fighting compartmentation are required. The drawings shall represent all these details including allowed tolerances values, gaps, etc.

3.15 Aesthetical and Ergonomic Characteristics

Materials and components shall be aesthetically acceptable and integrated in the environmental contest.

The General Contractor shall take care of the external surfaces finishing and provide protections, shelters, etc., wherever necessary.

The apparatus and devices for management and viewing shall be designed accordingly to the ergonomic requirements as specified in the EN 292, EN 614, EN 894, ISO 6385, ISO 9241.

3.16 Voltage Levels

The supply voltage may be selected from the following voltages:

- 1,000 V 3 phases +neutral (TNS)
- 3,500 V 1 phase + neutral (6 kV system)
- 400 V 3 phases + neutral
- A constant current system of 20 A with max supply voltage of 2.8 kV.

It was informed that ENEL will provide power supply to the bridge at 20kV level.

3.17 Pipes and Ducts Tightness

The Pipes and Ducts for liquids shall be fully tight. No water, oil, grease or air leakage shall be accepted.

The fluid discharges shall be collected and evacuated by using proper circuits.

3.18 Corrosion Protection

The General Contractor shall consider the environmental condition and the installation places to select the materials and equipment to be installed.

The air conditioned buildings, shall be designed by taking into consideration the possible break down of the conditioning plant.

The material subject to environmental damages shall be superficially protected.

No hygroscopic or subject to musty and fungus growth material shall be used.

All the metallic materials, steel structures, cable trays, supports, grids etc. shall be intrinsically corrosion resistant (i.e. inox material) or, whenever allowed, superficially protected through galvanisation or paints.

The electrical material shall be tropicalized and class B isolated, as minimum. Higher class shall be accepted providing that the heating class shall remain within the class B.

The small apparatus shall be provided with inox support material and screw. If these shall not be available in the market, the pieces shall be passivated or cadmium plated.

Electrical equipment must be provided with anti condensation heaters as required to eliminate condensations in switchboards and equipment.

When selecting materials and components due attention must be paid to the corrosive environment, especially to following climatic conditions:

- Salt-fog
- High relative humidity
- Condensation
- Galvanic corrosion
- Elevated temperatures.

The electrical and mechanical equipment shall be protected against corrosion with the aim to withstand the climatic conditions. specified in section 2.2 without further maintenance for a period of minimum 20 years.

The equipment shall be protected against effects of mechanical wear, grease or other liquids.

The specific requirements for pre-treatment and for corrosion protection systems shall be specified in the design.

3.19 Degree of protection by enclosure

3.19.1 General

The electrical and mechanical equipment shall be protected against ingress of dust and liquids.

The outdoor equipment shall be as a minimum protected against dust and low pressure jets of water: Protection degree minimum IP 55.

The indoor equipment shall be as a minimum protected against objects over 1 mm and direct sprays of water: Protection degree minimum IP 43.

Other requirements shall be as specified in the relevant requisition documents.

3.19.2 Tropicalisation and Prevention of Condensation

The equipment shall be tested for operating in extended humidity and temperature range under salt-fog conditions.

All enclosures shall be designed to minimise condensation, with provision for ventilation and drainage as appropriate. Openings for ventilation and drainage must not give access to sand, dust and salt-fog.

All electrical cubicles shall be equipped with suitable dimensioned electric heaters for automatic humidity control.

All materials that are exposed to direct sun radiation shall be made of UV-resistant materials.

The documentation for temperature, humidity and salt-fog tests in accordance with the relevant standard tests specified in the section 2.2.2, table 2.2-1 shall be provided.

3.19.3 Protection against Insects and Vermin

All equipment shall be designed to withstand attack from insects, vermin such as rats and rodents.

Preservation shall be carried out by means of careful selected materials, chemical preservation and mechanical barriers.

All enclosures containing electrical or mechanical equipment shall be provided with gaskets, steel mesh or similar mechanical barriers to ensure effective protection against intrusion.

3.20 Environmental pollution

NOISE POLLUTION

All the equipment and auxiliary components shall be designed to reduce the noise impact through sound, vibrations etc.

The following “Sheet of Conditions - Attachment A to CIPE dated 1 August 2003” shall be considered during the design phase :

"*Particular care shall be given during the Definitive Design of the Bridge secondary steel structures (lighting poles, etc…) to verify the noise due to the wind above the assumed design speed (10 m/s) and provide data collected from structures similar to the ones of the Bridge…"*

The noise limits for the machinery, components….shall not exceed the NR 78 curve ISO 1996, that are fixed in 85 dB (A) maximum.

CHEMICAL POLLUTION

Sheet of Conditions. See Attachment A to CIPE dated 1 August 2003

Which is "concerning the water and polluted liquids drainage, either during the construction or during operation phase: During the Definitive Design, its necessary to foresee an evacuation network, a dispersion area or a cleaner."

LIGHTING POLLUTION

"The Bridge lighting system, shall be designed in order to minimise the sea Lighting impact.

This can e achieved by selecting lighting equipment on the basis of the photometric characteristics and by a proper layout.

The Definitive Design shall include drawings showing the isophot configuration either at deck and sea level" "Sheet of Conditions - Attachment A to CIPE dated 1 August 2003"

EARTHING AND EQUIPOTENCIAL BONDING

The General Contractor shall design an efficient earthing system and verify the equipotential connections of the steel structures as per applicable specifications.

The electrical and mechanical documentation shall be prepared in accordance with IEC Publication 60617 and 61082.

4 External Lighting Systems

4.1 General

The following external lighting systems shall be designed:

- Sea and air traffic lights
- Architectural lighting for Towers and Suspension System, including Deck
- Road lighting (including maintenance and operation lanes).

In general, the lighting system for the air traffic shall not affect the safety during the takeoff and landing operations (i.e. through threshold).

Furthermore during the design, the following shall be taken under particular care:

- Light intensity, to avoid aircraft threshold
- The light colour shall comply with the applicable standards
- Light layout, to avoid similitude to airport runway, routes….

Laser and high intensity LED floodlights installation, if allowed, shall be studied to meet the relevant standard and regulations. In general, LED lights shall be preferred, where possible.

All lighting luminaires shall be class II insulation (double insulation) in accordance with IEC 61140: Protection against electric shock.

The lighting system shall also reduce the impact against the sea traffic.

The external lighting systems include:

- Road lighting
- Illumination of the towers and the suspension cables
- Navigation warning lights
- Aircraft warning lights.

The systems shall ensure safe and comfortable operation of the bridge in case of lack of adequate natural illumination. They shall ensure the visibility and surveillance of the bridge.

4.2 Road Lighting

Table 4.1 Required illumination and luminance values for roads

Illumination or luminance	**Value**
Average horizontal illumination	30 lux
Ratio min/average illumination	0.32
Ratio min/max illumination	0.20
Average luminance	2.0 cd/m^2
Longitudinal uniformity	0.7
Comfort index	7

The road lighting system shall be based on luminaires with LED lamps.

The maximum voltage variation at the luminaires shall be kept within ± 5%.

The road lighting systems shall be automatically switched by the SCADA system, with possibility of manual override at the transformer substations for maintenance situations. The automatic switching will have staggered time delays in order to reduce the total inrush current at switch-on.

Reduction of the lighting level during hours of low traffic intensity is provided. This function is controlled by CMS/SCADA.

The road lighting shall be designed to minimise power consumption and spill light, and to facilitate maintenance.

The daytime appearance of the road lighting installations shall be closely coordinated with the landscaping and architectural features of the bridges during the detailed design phase.

Luminaires shall be totally closed, full cut-off type with adjustable mirror optical system.

There shall be two luminaires on each pole. Each of these two luminaires will be connected alternately to the two backbone cables in order to limit the consequences for traffic safety of a fault in one transformer substation or high voltage feeder or in one backbone cable.

4.3 Architectural Lighting

4.3.1 General

The illumination shall provide a pleasant and uniform luminance of the surfaces of the bridge structures. The luminance level shall be kept low, approximately 2-10 cd/m^2.

The final detailed design of the floodlighting systems shall optimise the uniformity of the luminance, and shall minimise light spill and consequently light pollution. The lighting patterns caused by scattered light in foggy weather conditions shall be particularly addressed during the design.

The luminaires shall be directed or screened to prevent any glare in the directions of road and sea traffic.

The aesthetical lighting systems shall be automatically switched by the CMS/SCADA system, with possibility of manual override at the transformer substations for maintenance situations. The automatic switching shall have staggered time delays in order to reduce the total inrush current at switch-on.

The functioning of the lighting systems shall be monitored by the CMS/SCADA system by monitoring the current of each final circuit supplying the lamps, with alarm for currents below 90% of the steady-state current measured with all lamps functioning.

4.3.2 Towers

The towers and cross beams shall be illuminated by means of a architectural lighting. The ratio between the luminance of the lighted surface and the environment luminance shall be 30/50 - 1. The classical lighting may be based on metal halide floodlights.

The illumination shall provide a pleasant and uniform luminance of the surfaces of the bridge structures. The luminance level shall be kept low, approximately 2-10 cd/m^2.

The final detailed design of the floodlighting systems shall optimise the uniformity of the luminance, and shall minimise light spill and consequently light pollution. The lighting patterns caused by scattered light in foggy weather conditions shall be particularly addressed during the design.

The luminaires shall be directed or screened to prevent any glare in the directions of road and sea traffic.

Alternative systems may be considered to limit the light pollution for instance the systems utilizing fibre optics.

4.3.3 Suspension System

The hangers of the suspention system shall be lighted.

.The lighting shall be carried out by means of spotlights providing very narrow light in order to avoid light spill.

4.3.4 Superstructure

In order to complete the visual night time impression of the Bridge, and to outline the structure for the sea traffic, the underside of the bridge girder shall be illuminated.

4.3.5 Luminaires

The illumination of bridge structures shall be provided by floodlight luminaires with LED lamps, which produce a white light (colour temperature within 3000 - 5000 K) with good colour rendering (R_a > 80).

The following luminaire types are envisaged:

- Type "A" for illumination of hanger cables, narrow light distribution, 0.5 max I within ± 4º
- Type "B" for illumination of the underside of the bridge girder, narrow/wide light distribution, 0.5 max I_0 within ± 5º, 0.5 max I_{90} more than ± 30º
- Type "C" for illumination of the tower structures, very narrow light distribution, 0.5 max I within ± 2.5º

- Type "D" for supplementary illumination of main cables at positions without hanger cables, low intensity obstacle light type luminaire with omnidirectional light distribution, max I = 25-40 cd.

The final selection of luminaires and their positions shall be based on detailed calculations of the illumination. No luminaires shall cause any glare in the directions of the road traffic or the navigation channels.

All luminaires shall be corrosion resistant, and have degree of protection by enclosure at min. IP 55.

All luminaires shall be mounted in positions accessible for maintenance, or they shall be mounted on movable and lockable supports which can bring the luminaires into maintainable positions.

All luminaires shall be equipped with bird spikes or equal to prevent birds from resting on the luminaires.

A suitable number of laser aiming devices shall be delivered along with each luminaire type.

4.4 Navigation Warning Lights

The General Contractor shall design and install the lighting system of the Bridge and the Straight accordingly to the applicable rules, standards and requirements provided by the Marine Authority (i.e. COMANDO ZONA FARI – " MARIFARI MESSINA").

Red and green leading lights, white range lights and alignment lights will equipped with long-life, extra-low voltage incandescent lamps in automatic lamp changers containing up to 6 lamps.

The effective range of the lights shall be 7.5 - 10 nm.

The operation will be monitored by current sensors, and will, together with "Last lamp in use" be signalled to the CMS/SCADA system.

4.5 Aircraft Warning Lights

This system shall be designed accordingly to the ICAO, International Civil Aviation Organization, (Annex 14 – Volume 1° - chapter 4°) and "Regulation for the airport construction and operation"- ENAC, OAC, NIKAO standards.

White, flashing aviation warning lights of high intensity shall be located at the top of the towers and at the lowest point of the catenery.

The distance between the lamps, the lights' power and size shall be fixed as per above standards and regulations. The lamps shall be omnidirectional and double type; the intensity of the light emission (white), shall be adjustable.

The warning lights shall be divided into two equal subsystems, each system covering one tower and a half of the bridge. Each system shall be supplied from a dedicated switchboard located close to the respective tower.

The aircraft warning lights shall have at least 3 hours UPS back-up.

Aeronautical obstacle lighting for the towers shall be high intensity flashing white lights mounted for full visibility from all bearings. The intensity will be automatically adjusted by photocell control / CMS/SCADA in accordance with the background lighting (full sun, twilight or night).

Aeronautical marking of the cable stays - if required - shall be medium intensity red lights, flashing or fixed, pending further investigations and clarification of the requirements of the authorities.

5 Internal Lighting and Power

5.1 General Requirements

Internal lighting shall be installed in the external areas and in the internal volumes (bridge deck, towers, crossing beams, anchor blocks etc.) to allow operation, inspection and maintenance activities.

This lighting system shall be supplied from an uninterruptible power supply (UPS) to allow evacuation and increase safety in case of power supply failures.

All the maintenance and inspection routes shall be provided with power sockets (at intervals of 30 meters) for tools or auxiliary lamps connection.

5.2 Interior Lighting

The installations include interior lighting and power in all parts of the bridge that are accessible for inspections, maintenance or service.

An average illumination level of minimum 200 lx shall be provided at all areas where regular work, maintenance or operation takes place. The uniformity (E minimum/E average) shall be ≥ 30 %.

An average illumination level of minimum 30 lx shall be provided along walkways. The uniformity (E minimum/E average) shall be ≥ 30 %.

Emergency lighting along access ways / escape routes, as well as at working area shall be provided.

The emergency lighting shall provide minimum 3 lx. The uniformity (E minimum/E average) shall be ≥ 5 %.

Luminaires shall be manufactured in such a way that it is easy to replace lamps by using common hand tools. All interior lighting shall be LED lighting.

Unless otherwise specifically mentioned, lamps shall be of a type with a long lifetime, i.e. not incandescent, and the ballasts in the luminaires shall be magnetic, not electronic.

At every 90 metres, where the fire hydrants are located, a spot light luminaire shall be provided. These spot light luminaires shall automatically switch on in case of fire.

Every third of the internal luminaires shall be equipped for emergency lighting by being supplied from an uniterruptible power supply (UPS) with minimum two hour back up time.

The emergency lighting shall switch on automatically when the power supply to general lighting circuit is off for any reason.

The luminaires shall have reinforced not inflammable polyester and be able to function at an ambient temperature of 55 degrees Celsius. The IP code shall be 65 and the security class shall be II (double insulated). The vandal class shall be: Class II.

The spot light luminaire at the fire hydrants shall be able to withstand the effect of UV radiation. The IP code shall be 65 and the security class shall be II (double insulated). The vandal class shall be II.

5.3 Socket Outlets

All the maintenance and inspection routes shall be provided with power sockets (at intervals of 30 meters) for tools or auxiliary lamps connection.

All socket outlets shall have a screwed-on cover to the outlet, providing a degree of protection min. IP 56, and be impact proof.

Socket outlets (except where one single outlet is required) shall be placed in clusters (or built together as a switchboard assembly).

A cluster shall as a minimum contain:

- One 230V AC (1 phase + neutral + earth), 16 A switched socket outlet.
- One 48V AC (1 phase + neutral), 32 A switched socket outlet.
- One 24V AC (1 phase + neutral), 16 A switched socket outlet.

The 230 V socket outlets shall be protected against indirect contact by residual current circuit breakers.

The 48 V and 24 V socket outlets shall be supplied via a step - down safety transformer providing galvanic isolation from the network.

6 Road Traffic Management System

6.1 General

This chapter states functional specifications of the Road Traffic Management System (RTMS) for roadway traffic on the bridge.

The main characteristics of the RTMS are:

- the RTMS shall allow operators in the Traffic Management Centre (TMC) to maintain an overview of current road, weather and traffic situations on the bridge.
- the RTMS shall allow operators in the Traffic Management Centre (TMC) to execute and control all required dynamic traffic management operations on the bridge remotely from the TMC.
- the RTMS shall be implemented as a distributed control system, which through a number of local sub-stations (LSS) collect data to the RTMS central system and transmit commands from the RTMS central system to the roadside equipment through the LSS'.

- the RTMS shall be an integrated part of the SCADA system and will use the SCADA system's Man-Machine-Interface for input of control instructions from operators and display of status and events.

The key objectives of the RTMS are:

- to manage the traffic flow according to changing actual traffic, road and meteorological conditions achieving efficient and safe passage for road vehicles on the bridge
- to provide a system basis for continuous provision of traffic data for traffic analysis purposes - primarily traffic statistical purposes and simulation of extreme situations for training purposes

The RTMS shall comprise the following main function groups:

- traffic management
  - traffic monitoring
  - traffic information
  - traffic control
- incident management
  - incident monitoring
  - recovery coordination
- off-line traffic management simulation
  - replay of recorded incidents and traffic information
  - verification of management scenarios
- technical system operation and maintenance
  - monitoring of all RTMS systems and modules
  - monitoring of all communication infrastructure.

For asset management and other system administrative functions the general functions built into SCADA shall be used.

6.2 Communication Infrastructure

In general communication within the RTMS and between the RTMS and other systems shall be realised on the basis of the redundant fibre optical data network spanning the entire bridge and connecting the bridge with the TMC.

However, detectors and actuators (e.g. VMS, barriers etc.) attached to LSS' shall be connected to a local field network managed via the LSS' in order to allow local monitoring and control to be performed without reliance on communication between the TMC and the LSS.

Each data connection shall be monitored for problems and failure.

6.3 Traffic Monitoring

Traffic monitoring is responsible for providing all real-time traffic information required for dynamic traffic management to be performed.

Traffic monitoring is also responsible for archiving traffic information for later use in statistical analysis, traffic simulation, verification of traffic management scenarios etc.

6.3.1 Automatic monitoring of Road Traffic Parameters

Automatic acquisition of required traffic parameters shall be accomplished through LSS's and detectors installed in the roadside or above the traffic lanes depending of applied technology.

The following traffic parameters shall be monitored:

- Traffic speed
- Traffic volume and density.

The system software shall log the traffic data in a Traffic Database with the following information:

- For each vehicle: Speed
- For each lane: Traffic volume, average speed

- For the Bridge: Total traffic volume.

All data shall be reliably time stamped as close to the origin as possible in order to provide high traceability. The traffic information shall also be tagged with geographical origin making it possible to identify exactly which detector has provided the information.

6.3.2 Visual Monitoring

A CCTV system shall provide TMC operators with 24/7 realtime visual coverage of the entire roadway system on the bridge. the visual coverage shall be used as basis for the operators evaluation of road, weather and traffic conditions on the bridge in conjunction with the realtime traffic information provided by the automatic monitoring system (see section 6.3.1). Further, the visual coverage shall act as an important support tool to TMC operators performing incident management.

The CCTV system shall provide full motion (25 frames/sec) full colour images in a resolution sufficient to perform as follows under any foreseeable set of circumstances:

- enable TMC operators to distinguish individual vehicles and persons anywhere on the bridge
- allow automatic incident detection (AID) to be performed on the basis of the streamed video information (see section 6.4.2 for requirements to AID)

In addition to the general video surveillance provided by the above described CCTV function, dedicated cameras shall be added to the CCTV system for Automtic Number Plate Recognition (ANPR).

Any TMC operator shall be able to select live video feed from any camera - or any combination of cameras - in the CCTV-system, for display on his own workstation monitor and/or on the video wall system in the TMC. All video feeds shall have encoded information about time and place of recording and compass orientation of camera.

6.4 Incident Management System

The RTMS shall be provided with an Incident Management System (IMS) covering the following functions:

- Automatic Incident Detection

- Event verification and logging
- Incident Management.

6.4.1 Automatic Incident Detection

Automatic Incident Detection (AID) shall be implemented on the basis of a CCTV system with automatic video processing software aimed at detecting the following incidents:

- Stationary vehicles in any lane (incl. emergency lanes)
- Stationary vehicles in any lay-by
- People on the roadway
- Lost goods on the roadway
- Slow moving traffic in any lane.

The CCTV system shall have enough cameras installed to assure full AID functionality on all the roadway surface on the bridge.

Cameras providing video information for the AID function shall be fixed (i.e. not PTZ-type) and shall be able to provide a video quality that availability of the AID function 24/7 in all foreseeable environmental conditions.

6.4.2 Incident Management

The RTMS shall be provided with incident management facility with the following functions:

- Preparation of response plans for clearance of accidents and their presentation to the Operator. The predefined plans shall cover all major functions to be handled by the Operator in case of accident.
- Automatic information to road users via VMS signs and text.

The system shall be prepared for predefined response to typical accidents, e.g.:

- Major accident
- Weather conditions

- Stalled vehicle
- Lost goods.

Information on weather conditions shall be obtained from sensors belonging to Structural Health Monitoring System/Weather Monitoring System.

6.4.3 Event Verification and Logging

All incidents detected are required to be verified. The system shall be provided with an incident verification form for a formal registration and storing of events.

Each verified event shall be stored in an Incident Database.

Verification of events shall be protected with a password.

All recorded events shall be accessible for later use for event analysis and for use in traffic simulations on the Simulator and Training Console.

6.5 Data Processing and Management

The system software shall be based on an industry standard software package with performance and quality proven in other similar RTMSs.

All data stored in the RTMS system database shall be accessible by the SCADA system through SQL queries.

The RTMS shall be capable of providing storage for selected historical data for a period of at least 10 years on hard disks and for an unlimited time on magnetic tapes or similar technology.

The LSS shall be equipped with data storage system capable of accepting data from the field equipment even in case of failure of the communication to the RTMS. The LSS archiving system shall be capable of retaining a minimum of 200 hours of unprocessed information, without operator attendance regardless of the sampling regime in force.

After reconnection of the data network to RTMS, the LSS shall transmit buffered data to RTMS so that the database of the RTMS holds a complete series of data regardless of any communication breakdown period less than 200 hours.

All data collected by the RTMS field equipment shall be tagged and time stamped where first stored, so that data always can be traced back to specific traffic at a specific location.

All real time data shall be stored in operation database within the RTMS central computer. The operation database shall store all data for a one month period. Data necessary for reports and statistics shall be transferred to a historic database. The historic database shall be designed with a capacity to hold 10 years data.

A number of data shall be transmitted periodically to SCADA. Alarms are transmitted to SCADA in real time.

The RTMS shall have a clock function capable of keeping permanent synchronisation with an external clock source to within +/- 10 ms.

6.6 Data Monitoring

All video records shall be displayable on:

- Operator workstation display units
- Large display wall in traffic management centre.

All logged operation events shall be accessible to the RTMS operators.

All data shall be accessible for data presentation including:

- Local monitors/operator consoles
- Large display walls in the Control Room
- Custom designed reports
- Custom designed data presentation pictures, graphs and curves.

The configuration and layout of diagrams, pictures, reports, graphs, etc. shall be defined in cooperation with the Owner in connection with the detailed design of the system.

6.7 Computer Hardware

6.7.1 RTMS Central Computer

The RTMS' Central Computer shall be installed in the traffic management centre in the Bridge Control Room located in the Bridge Administration Building approximately 2 km from the Bridge Abutment in Calabria.

The central computer shall consist of computers/servers which together shall comply with the following minimum specifications:

- Redundant system with duplication of all hardware and software, automatic detection of failure in the active system and taking-over by the standby system in a hot-standby configuration.
- Newest technology.
- MTBF not less than 1 year.

6.7.2 Local Substations

Local sub-stations for connection of the RTMS field equipment shall be installed in the field on the bridge deck, abutments and towers.

The local substations shall be constructed on the basis of distributed computers which together shall comply with the following requirements:

- Redundant system with duplication of all hardware and software, automatic detection of failure in the active system and taking-over by the standby system in a hot-standby configuration.
- Newest technology.
- MTBF not less than 1 year.

All LSS' shall be supplied from uninterruptible power supply (UPS) capable of support their function for at least 24 hours in case of failure on the power supply network.

6.8 Moveable Barriers, Bridge Access

Moveable barriers shall be installed landside immediately north and south of the bridge. The purpose of these barriers shall be to prevent any traffic from entering the bridge in cases where accidents or adverse weather conditions makes traffic on the bridge unwanted or unsafe.

The barriers shall be remotely controllable electro mechanical devices that efficient block both traffic lanes. Blocking of the emergency lane shall operate independently from blocking of the traffic lanes in order to allow passage of rescue vehicles onto the bridge.

The barriers shall be equipped with three sets of flashing red lights. Each set of lights shall flash alternatingly.

6.9 Retractable Barriers, Cross Over Access

Retractable barriers shall be installed in parallel with the left crash barriers in a manner that allows cross over openings to be established when needed. When access to crossing over is not required, the barriers shall act as a fully integrated extension to the left side crash barrier providing the same protection to traffic as the normal crash barrier.

The barriers shall be remotely controllable electro mechanical devices capable of efficient blocking access to crossing over respectively providing access to crossing over.

6.10 S.O.S stations

The S.O.S stations shall comply with the following specification:

This System and all the relevant equipment, shall be of the same model and manufacture of those installed along the connection infrastructures.

The SOS column shall be installed at 500 m distance from each other on both side of carriageway.

The position of SOS column shall be defined by taking into consideration the cross beams position, the VP, signage, lay-by, etc.

6.11 Variable Message Signs (VMS), Text

VMS shall have the following specifications:

- Fully remotely controllable from the traffic management centre.
- VMS's based on light emitting technology shall have a built-in intensity control, that adjusts emitted light according to intensity of background light and direct light onto the VMS surface.
- Free format text with three rows of 20 characters each.
- Display colours: yellow, yellow/white, white matrix dots on black background as class C2 of EN12966.
- Detailed feed back on operational status.

On bridge sections where two-way traffic shall be supported, the VMS shall be dual-faced.

6.12 Variable Message Signs (VMS), Speed Limits and Other

VMS for displaying dynamic speed limits and other messages shall have the following specifications:

- Speed limits: display of 3 ciphers, in any legal combination.
- Queue. pictogram like (but in contrasting layout).

- slippery road: like (but in contrasting layout except for red triangle)

- accident: like (but in contrasting layout except red triangle)

- two-way traffic: like (but in contrasting layout except red triangle)

- Remotely controllable from the traffic management centre

- Based on light emitting technology with built-in intensity control, that adjusts emitted light according to intensity of background light and direct light onto the VMS surface
- Detailed feed back on operational status

On bridge sections where two-way traffic shall be supported, the VMS shall be dual-faced.

6.13 Lane Control Signal

Lane Control Signals (LCS) shall be installed under the portal cross beams, centred above each lane . On bridge sections where two-way traffic shall be supported, the LCS shall be dual-faced. The LCS shall have the following minimum specifications:

- Capable of displaying any of the following symbols - one at a time: "green down arrow" (lane open), "yellow left arrow" (merge left), "yellow right arrow" (merge right), "red diagonal cross" (lane closed)
- Road users shall experience clearly distinguishable symbols at 100 m distance under any foreseeable environmental conditions

7 Power Supply and Distribution

7.1 General

The power supply and distribution works cover establishing of reliable power supply and distribution system providing power to the installations on the bridge. The main components of the power distribution system are:

- Main power supply substation at Calabria side of the Bridge QMT-SS-Calabria 20 kV switchgear and 20/6 kV transformer.
- Main power supply substation at Sicily side of the Bridge QMT-SS-Sicily 20 kV switchgear and 20/6 kV transformer.
- Emergency diesel power supply station at Calabria side of the Bridge.
- Emergency diesel power supply station at Sicily side of the Bridge.
- Distribution substations on land in Calabria QMT-G-Calabria.

- Distribution substations on land in Sicily QMT-G-Sicily.
- 8 Distribution substations on the Bridge QMT-A1 to QMT-A8.
- Uninterruptible power supplies (UPS) at location of the UPS loads.
- The power supply to the traction system for the railway is not a part of these works.
- Medium voltage cable system.
- Low voltage cable system.

7.2 Power Analysis and Calculations

7.2.1 Load Types

Basis types of electrical loads are: lighting, telecommunication, monitoring and technological systems such as: dehumidification, elevators, fire fighting and water supply.

7.2.2 Loads Classification

The electrical loads shall be classified as follows:

a) Critical loads with a local or centralized UPS system

- Control Room equipment
- Monitoring and supervision instruments
- Sea and air traffic lights
- VS panels (Variable Signal Panels)
- Telephone and data transmission
- Safety lighting

b) Critical loads with independent units of emergency:

- Anti-intrusion, alarms…

c) Essential loads with back-up supply from emergency generators:

- Elevators
- UPS
- Road Lighting (depending on the anti-sabotage and risk analysis. UPS feeding shall be available for a certain number of road lamps).
- Internal lighting and maintenance routes lighting.

d) Normal loads connected to the automatic transfer switchgear (with possibility of disconnection in case of ENEL failure)

- Power sockets
- Dehumidification system
- Hoists

e) Normal loads connected to switchgears without automatic Transfer.

- Architectural lighting and catenaries

7.2.3 Power Demand

Power demand shall be calculated based on power consumption during operation of E&M equipment during both night and daylight periods.

Furthermore, the power demand shall be separately calculated for the following operation conditions:

- Normal operation
- Operation without power supply from ENEL.

7.2.4 Fault Analysis of Power Systems

A Failure Modes and Effects Analysis (F.M.E.A) and Fault Tree Analysis(F.T.A) in relation to the installations is covered by this part of the Works.

7.3 System Configuration and Operation

To ensure high availability of the electrical power the power supply must consists of two redundant substations, QMT-SS-Sicily and QMT-SS-Calabria supplied from the national grid.

Table 7.1 Location and number of main components

Location	Description	Number	Remarks
QMT-SS-Sicily QMT-SS-Calabria	20 kV switchgears	2	
QMT-SS-Sicily QMT-SS-Calabria	20/6 kV transformers	2	*See footnote*[1]
Towers	6/0.4 kV transformers	4	
Anchor blocks	6/0.4 kV transformers	2	
QMT-G- Sicilia QMT-G-Calabria	6.0 kV switchgears	2	
QMT-G- Sicilia QMT-G-Calabria	Emergency generators: 6 kV	2	
QMT-A1, A3, A5 and A7 Bridge West Side	6 kV /0.4kV substations	4	
QMT-A2, A4, A6 and A8 Bridge West Side	6 kV /0.4kV substations	4	

[1] The necessity to have redundant transformers in both 20kV substations has been discussed. It is found that sufficient redundancy is obtained by enabling all loads on the bridge can be fed from either QMT-SS-Sicilia or QMT-SS-Calabria.

7.3.1 Operation Modes

NORMAL OPERATION

During normal conditions each of the 20 kV switchgears shall supply half of the total electrical load.

EMERGENCY OPERATION

If one of the 20 kV substations fails the other 20kV substation and the electrical distribution system must supply the total load of the bridge. Each of the 20kV substations must be dimensioned to feed 100% of the bridge loads.

In case of failures in 20 kV substations or feeders from ENEL the emergency generators can feed all consumers. Each of the generators must be sized to cover 50% of the total bridge load.

None of the electrical power supplies will run in parallel and no synchronisation between the systems will be required. On switching between the systems it is acceptable to have a power cut.

Systems not accepting a power-cut must have UPS power back-up to cover the transition period.

7.3.2 Distribution Voltages and Topology

The loads on the bridge shall be supplied through 6/0.4 kV transformers located along the bridge to ensure:

- Reduction of weight and cross section of electrical cables
- Easier installation and maintenance
- Easier installation of compact transformers.

Selection of 6 kV voltage level facilitates the generation of energy directly on 6 kV level by means of 6 kV emergency alternators.

Two 20/6.0 kV switchgears shall be located in proximity of the towers, where also the ENEL MV feeders shall be located.

The QMT-G-Sicilia and Calabria substations must feed the towers and bridge. The Ancor Blocks must have their own transformers feed directly from the ENEL grid and will be independent of the other electrical systems on the bridge.

The above-mentioned topology of MV/LV shall be chosen to ensure reliability, safety and a minimum of maintenance.

Table 7.2 Distribution Voltages

Location	Nominal Voltage V
QMT-SS switchgear Sicilia	20/6
QMT-SS switchgear Calabria	20/6
Anchor block	6/0.4/0.23
Tower high altitude	6/0.4/0.23
Tower low altitude	6/0.4/0.23
Deck	6/0.4/0.23

7.3.3 Monitoring of the Power Supply System

All transformer and switchgear cubicles shall be monitored and controlled by a computer-based Power Management System (PMS). The data transmission shall be based on protocols with data rate >1.5 Mbps to ensure exchange of information in real time. The network shall be of deterministic type.

7.4 Uninterruptible Power Supply (UPS)

The UPS must maintain the power supply to the equipment which do not accept a power cut or where a power cut is unacceptable for safety reasons. The UPS must maintain power for these loads for a minimum time of 30 minutes or higher if required for any safety reasons.

7.5 MV Cables

Table 7.3 Types of cables MV

From-To	Operation Voltage (kV)	Type	Specification
20 kV ring QMT-SS Calabria-QMT-SS Sicilia	20	RG7 H1 OZR	3 cores Armoured
From QMT-SS To 20 kV transformers	20	RG7 H1R	1 core
From QMT-G switchgear to bridge deck and towers	6	RG7 H1 02R	3 cores Copper shield Armour galvanized steel

7.6 LV distribution system

The LV power distribution system must be a radial system distributing the power from the 400/230V substations to the electrical loads. Nominal voltage of the system is 400/230V with earthed neutral.

No redundancy is to be provided in the LV distribution system. But any lighting installations in an area must as a minimum operate on two independent circuits. It is acceptable to switch off the lighting installations on a power supply transfer when the distribution system is switched. E.g. changing from Emergency Generator back to normal ENEL supply.

7.6.1 LV power cables

Table 7.4 Types of cables LV

From-To	Voltage (kV)	Type	Specification
Downstream main LV switchgears and secondary LV switchgears	0.6/1	FG7(0)M1	Single core Lowest emission of smoke and toxic gases according to CEI 20-37 and 20 38
Power supply of motors	LV	N1VVK	single core or multi core
Power supply of lighting circuits and fans	LV	N07V-K	single core
Power supply of lighting circuits and others where max personal safety shall be granted	LV	N07G9-K	3 or multi cores
Power supply of security circuits	0.6/1 kV	FG10OM FG10M10	3 core single core

8 Lightning protection

The lightning protection of following structural elements shall be designed:

1 Lightning protection of towers.

2 Lightning protection of anchor blocks.

3 Lightning protection and earthing of the bridge deck.

4 Equipotential bonding of all steel constructions and elements of the bridge.

5 Provisions for earthing of E&M installations on the deck and in the towers and anchor blocks.

The Failure Modes and Effects Analysis (F.M.E.A) and Fault Tree Analysis (F.T.A) in relation to the lightning protection installations covered by this scope of the works shall be carried out.

The following systems are not a part of the present design:

- Lightning protection and earthing of the railway systems (Railway system design)
- Lightning protection of the primary substation buildings (part of the Land works design)
- Lightning protection of the Management building (part of the Land works)

8.1 Standards

The lightning protection system and installations shall comply with the CEI, EN end IEC standards specified in the table below.

Table 8.1 Specific Codes and Standards for Lightning protection systems and earthing.

Description	Norm or Standard	
	CEI or UNI	**EN or IEC**
Protezione delle strutture contro i fulmini	CEI 81-10/1 to 4	EN 62305
Lightning protection components		EN501164
Protection against lightning electromagnetic impulse		IEC 61312

8.2 Analysis of Risks during Lightning Discharges

A Failure Modes and Effects Analysis (F.M.E.A) and Fault Tree Analysis (F.T.A) shall be carried out in order to detect possible risks to both Bridge structures and its electrical and mechanical installations during lightning discharges, as well as to prove the robustness.

Results of these analyses shall be a part of the design necessary for the manufacturing of equipment and for the installation works.

8.3 Other Design Criteria

The frequency of lightnings in the region is in average 1.5-2.5 year/km^2, however higher frequency must be expected around the bridge.

8.4 Towers

The steel construction of the tower forms a natural air termination and down conductor. The construction consists of a number of steel sections and cross beams. The joints of exterior plates are welded by complete penetration welds and the joints of interior plates and stiffening bars are bolted. It is foreseen that the electrical conductance of the joints is sufficiently high to ensure equipotential bonding of the sections and the crossbeams.

The tower cross beams are constructed of steel and shall be used as the earthing conductor for electrical and mechanical installations located in the cross beams.

8.5 Tower Foundations

The reinforcement of tower foundations shall be equipotentially bonded with the steel construction of the tower and grounded. The reinforcement bars are in a direct contact with the concrete, i.e. are not insulated from the concrete by an external insulation sheet such as epoxy resin.

As a minimum requirement rings shall be constructed of horizontal steel reinforcement bars and wires interconnected by means of connection clamps. A ring shall be constructed for approximately each 10 m of the foundations depth, starting from the bottom of a foundation. Each of the rings shall be connected to the vertical reinforcement bars (down conductors). Each down conductor consists of at least two (2) reinforcement bars. The down conductors shall be interconnected. The minimal number of down conductors is four (4).

The uppermost rings shall be equipotentially bonded to the basis steel construction of the tower.

From the uppermost ring outlet connections shall be provided to outlets casted in the concrete of foundation above the ground level. All outlets shall be prepared for connection to equipotential bonding bars.

The earth termination shall be constructed as a mesh network by means of reinforcement bars jointed together in the bottom of foundations, the mesh size max. 2x2 m.

The down conductors shall be connected the earth termination network.

8.6 Anchor Blocks

The steel reinforcement in concrete substructure of the anchor blocks is used as the earthing system in the similar way as the structural reinforcement of towers.

8.7 Main Cables

The cables shall be protected to avoid damage by a lightning stroke, of the polyethylene polymer insulation sheet covering the steel core of the cables.

The hand ropes shall be utilized for the lightning protection. The hand ropes shall be equipotentially bonded with steel core of both cables every 30 m by means of a clamp (collar).

The main cables shall be equipotentially bonded by means of the cable saddle with the steel construction of the top of the towers.

The anchorage of suspension cables shall be equipotentially bonded to the steel reinforcement of the anchor blocks. The following anchorage elements shall be connected to the steel reinforcement:

1 Splay saddle

2 Anchorage shoes

3 Anchorages for post-tensioning.

There shall be two independent bonding connections between each of those anchorage elements and bonding rings in the reinforcement of anchor blocks.

8.8 Hangers

Equipotent bonding between the hangers and the main cables and between hangers and deck cross girders shall be established where the mechanical junction do not have sufficient lightning current carrying capacity.

8.9 The Deck

The Bridge deck is constructed of steel and shall be used as continuous earthing conductor for electrical and mechanical equipment located on the deck. To ensure continuity the expansion joints and bearings must be equipotentially bonded by means of flexible connections.

The buffers between the deck and the towers shall be bonded by flexible connection to prevent electrical lightning currents through the buffers.

The deck shall be equipotentially bonded with the outlets in the tower foundation.

The deck shall be grounded at the connection with Sicilia side and at the connection with Calabria side. The earthing connections shall be made to earthing electrodes installed in the ground. The resistance of these electrodes shall be below 2 ohms.

8.10 Provisions for Lightning Protection of E&M Installations and Systems

8.10.1 General

Outlets for bonding and earthing of the electrical and mechanical installations such as pipes, staircases, valves, switchboards and transformers shall be provided. The installations shall be equipped with lightning protection including shielding, equipotential bonding, surge protection and earthing provided by others.

8.10.2 Installations in Towers

In order to prevent flashover between the steel construction of tower and E&M installations in the girders, the installations shall be equipotentally bonded with the steel construction. For this purpose earthing outlets (earthing connections) shall be installed on the interior wall of the tower.

8.10.3 Installations on Deck

All E&M installations and equipment shall be electrically connected to the steel structure of the deck. For this purpose bonding outlets shall be installed at the deck.

The total number of earthing connections at the deck amounts to about 500 connections for mechanical and electrical installations.

8.10.4 Installations in Anchor Blocks

The E&M installations and equipment shall be equipotentially bonded with the earthing outlets in the anchor structure.

8.10.5 Electrical Cables

The cables will be earthed in both ends. The earthing connection shall normally be located in the respective switchboards. The Sub-Contactor shall install additional earthing connections for the cables at the deck, towers and in anchor blocks if necessary.

8.10.6 Switchboards

Distribution boards will be equipped with surge protection devices. The co-ordination of surge protection will comply with IEC 61312.

9 Earthing Installations

9.1 General Requirements

Earthing shall be established in order to reduce the touch voltages and conduct all insulation fault currents to earth.

The earthing and bonding shall comply with the Low Voltage Directive 2006/95/EEC, IEC 60364 and IEC 61892. All electrical installations shall be TNS in accordance with IEC 60364.

9.1.1 Earthing in Electrical Rooms

Table 9.1 Earthing in electrical rooms

Requirement	Description
Electrical ring connection	Cross section not less than 50 mm^2
Earthing to the floor	Welded or other strong connection
Earthing outside the room	Copper bar, buried, depth 50 cm

Metallic structures	Connection with strong clamps, terminals or bolts

9.1.2 Equipotential bonding of structures of the bridge

The main bridge cables shall be bonded with the earthing system of the anchor blocks, terminal piers and the towers.

The steel reinforcement of the anchor blocks, towers foundations and terminal piers shall be used as natural componets of the lightning protection system (LPS) and form an earthing system and all metallic structures shall be connected by means of metallic connections to this earthing system.

10 Cable Ways

10.1 General Requirements

In general all electrical and communications cables shall be installed on cable trays or ladders.

10.2 Design Requirements

All cable trays or ladders shall comply as minimum with the requirements in the table below.

Table 10.1 Cable trays

Requirement to:	Description
Material	Stainless steel AISI 304L indoors and outdoors
	Glass reinforced plastic can be used where suitable
	Galvanized steel CEI 7,6 , minimum thickness of 18 micrometer Approval of the Committee is required.

Reserve in space	50 %
Minimum distance at passing data and control cables, telephone cables and other service cables	300 mm
Separation from other cables	Metallic separation between power cables and service cables
Expansion joints	Yes

11 Railway Traffic Management System

The railway traffic management system is not part of this Design Basis.

However information shall be exchanged with between the bridge control centre and the rail authorities in order to ensure the "safe" operation of the bridge.

As a minimum the following information shall be exchanged:

To the rail authorities - RFI:

- minimum time for next train to enter the bridge
- maximum weight of the next train to enter the bridge
- emergency information.

To the bridge control centre:

- Weight of the next train to enter the bridge
- Estimated time for arrival of the next train
- information about carried goods.

Information shall be exchanged on a serial protocol, specified by RFI.

The following interfaces to this system shall be clarified:

- Information to RFI in case of emergency situation on the bridge.

- Coordination of information exchange from RFI to the bridge control room.

11.1.1 Monitoring of Railway Traffic

The total real time weight will be added the weight of the railway trains informed by RFI and the system shall inform the SCADA Operator on:

- The total weight from vehicles
- Total weight of the train
- Total weight of the train and vehicles versus allowed weight during the specific weather conditions.

In case the total weight is higher than the permitted the Operator will be alarmed and shall analyse the situation and:

- Request RFI to stop the train
- Stop the traffic and allow the train to pass the Bridge.

11.1.2 Monitoring of Trains

The system will be provided with monitoring of train approaching and exiting from the Bridge.

The recognition of the train will be provided by means of video detection sensor. The video sensor will detect the train and read the train's recognition number. There will be two video detectors installed close to railway:

- One detector at the approach to the Bridge
- One detector at the exit from the Bridge.

The detection of the train will be result in the following actions:

- Information on the train's approach shall be transmitted to the SCADA
- Video picture of the train shall be displayed in the Control Room on the Traffic Display Screen, as long as the train is within the video image.
- Information on the train's exit from the Bridge shall be transmitted to the SCADA.

The sensor shall be based on a CCD video camera with integrated control and communication hardware prepared for data transmission to the Central TSM computer via fibre optical data network.

The sensor shall be equipped with failure detection.

The sensors shall be duplicated and arranged in a totally redundant system.

12 Management and Control System

12.1 General

The system for operation of the bridge shall be designed to support real-time monitoring and management of the road and railway traffic and provide sufficient means for management of bridge maintenance and preparation of analysis and detection of risks in case of extreme weather or/and traffic conditi0ns.

The bridge management and control system shall be interconnected with installations for all approaching parts of the traffic system.

This data input is not limited to daily operation events only, but shall focus also on short term and long term prediction of traffic volumes, maintenance needs and optimization of interventions in case of traffic restrictions due to weather conditions, special transports, traffic accidents and safety threats. This interface shall be clarified during “Projecto Definitivo” phase.

The system shall ensure the functions:

- Monitoring functions: Physical environment, the works, the traffic, the events, the maintenance, and the apparatus and subsystems.
- Supervision functions: anti-intrusion, anti-sabotage, anti-terrorism.
- Management functions: Traffic, including simulations and forecasts; sensors, equipment and subsystems; events; emergencies
- Coordination function
- Safety function: Risk management, infrastructure, users, systems

- Function of information of the state to Concessionaire, police, customers and others.

Language for planning of the system is UML (www.UML.org).

12.2 Scope of Works

The total Management and Control system shall cover functions specified briefly in section 11.1 and consist of the following individual systems interconnected together:

- Supervisory Control and Data Acquisition (SCADA) system.
- Management system for maintenance planning.
- Simulation system for structure loads and weather simulation.
- Traffic Management system (RTMS) for monitoring and management of road traffic, monitoring of railway traffic and traffic simulations.
- Structural Health Monitoring System (SHMS).
- Control and Monitoring System (CMS) for control and monitoring of technical systems (E&M).
- Power Management System (PMS)
- Safety System (SSS) for access control, anti intrusion and anti sabotage protection and CCTV surveillance.

The monitoring and management work stations and large screens for display of pictures and visualisation of alarms and operation data shall be located in common Control Room (Centro Direzionale) in Bridge Management building on Calabria side of the bridge. Location of the Bridge Management building shall be defined during the “Project Definitivo” phase.

The SCADA system shall be provided with communication access to the Railway Management Centre (RFI) and external authorities (police, local road authority, etc.).

12.3 System Configuration

The Management and Control system shall be designed as an integrated system which assure safe operation of the Bridge in any operational situation and provide tools for management of maintenance of the Bridge, risk management, training and simulations, as well as reliable

information exchange with administrators of interconnected highways and railways and external authorities.

All management, control and monitoring functions shall be transmitted to control room located nearby the bridge. It is recommended to establish an emergency control room in a separate location, if agreed with the General Contractor.

The system shall be configured as shown on drawing CG.10.00-P-DX-D-P-CG 00GC 00 00 00 06.

12.4 Supervisory Control and Data Acquisition (SCADA) System

The leading principles for the SCADA shall be:

- The SCADA shall be a distributed control system, which through a number of expert systems collect data to the SCADA system and transmit commands from the SCADA system to the field systems' local control units via the above expert systems. The expert systems are listed in section 12.4.1.
- The SCADA system shall provide Man-Machine-Interface for display of events reported by all expert systems and is de facto the main system for generation of commands, as well as is operating as the main interface between the Bridge Operator in the Bridge Control Room and the expert system sensors and remote control and monitoring equipment on the Bridge;
- The SCADA shall be very reliable system working with redundant hardware, redundant communication ways as well as fail tolerant software.
- The SCADA shall be provided with facilities for self-test and automatic detection of any operation failures.
- The SCADA shall be equipped with operation and historical data storage facilities.
- The SCADA shall be equipped with intelligent alarm log divided in prioritised alarm levels, alarm filtering, alarm acknowledgement facilities with access passwords.

The key functions for the SCADA system shall be:

- to provide total overview of the overall operation situation on the Bridge to the operation staff in the Bridge Control Room.

- to alarm the operation staff in the Bridge Control Room in case of any failure in the technical equipment of the Bridge.
- to alarm the operation staff in the Bridge Control Room in case of any safety related situation in the neighbourhood of the Bridge or on the Bridge.
- to provide facilities for remote operation of all electrically controlled equipment of the Bridge.
- to handle event communication to the Management and Administration System.
- to provide reporting facilities.
- to communicate with external computer systems for RFI, road operators and external authorities.

12.4.1 General Functions and Connected Expert Systems

All technological systems operations shall be monitored. The interfaces to these systems field equipment shall be included in these technical expert systems and the SCADA shall carry out its functions through the central computers of these systems.

The system functions are:

1. Monitoring of:
    - Physical environment and its actions (SHMS)
    - The Works during construction (SHMS)
    - The Works during operation (CMS, PMS, SHMS)
    - Traffic (TMS)
    - Events (SCADA)
    - Systems and sub-systems (SCADA)
2. Surveillance:
    - Traffic on the Bridge (TMS)
    - Against intrusion, sabotage and terrorism (SSS)

3. Management of:
    - Traffic on the Bridge (TMS)
    - Safety - intrusion, sabotage and terrorism (SSS)
    - Power Distribution System (PMS)
    - Data and telecommunications
4. Information to external parties:
    - RFI (SCADA & telecommunication system)
    - Operators of interconnected motorways (telecommunication system)
    - Police (telecommunication system)
    - Intervention/maintenance teams (telecommunication system)
    - Traffickers.

12.4.2 Specific Monitoring Functions

In general the following functions shall be provided by the technical expert systems in connection with monitoring of the systems:

- Operation status;
- Technical alarms and warnings;
- Operation time for each sub-system;
- Data communication failure;
- Safety related alarms;
- Measured values for technical measurements.

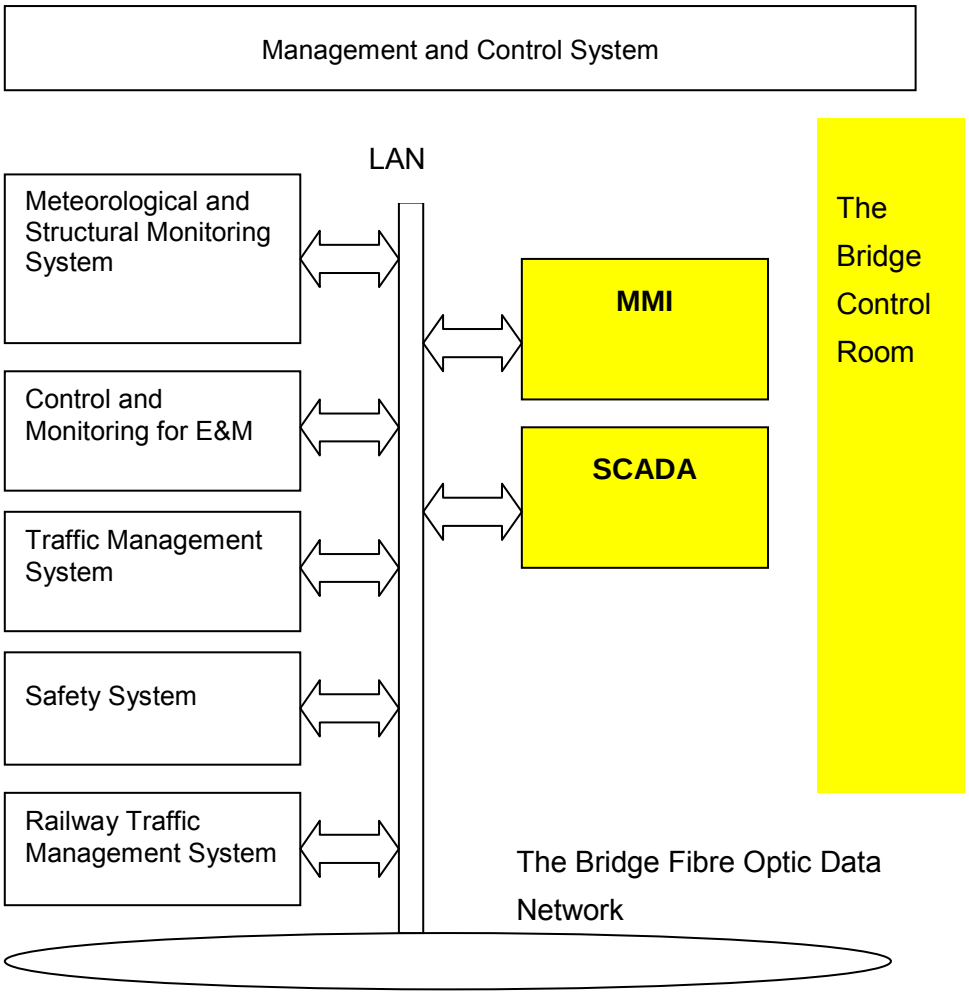

Fig. 12.4 Configuration of the Control and Monitoring System

12.4.3 SCADA Man-Machine Interface (MMI)

The SCADA Man-Machine Interface (MMI) shall be designed to view both the total Bridge and its details at the same time on a large display screen arranged by means of a multi-screen system or similar technology.

Furthermore, two Operator Consoles shall be used for detailed monitoring of SCADA functions by the SCADA system operators.

The display screen shall be freely addressable from each SCADA Operator Consoles. Furthermore, the display screen shall be addressable from operator consoles for the technical expert systems.

The display screen shall be divided into three sections:

- 1st section dedicated to the Traffic Management System for display of traffic situation and traffic management events;
- 2nd section dedicated to the SCADA and the technical expert systems including layout of systems, status indications for each system (operation status, alarms, failures etc.)
- 3rd section dedicated to the surveillance in connection with intrusion, anti sabotage and anti terrorism functions

A GIS interface shall be provided, through which the operators will be able to visualize on a geo-referenced map the real-time position of the technical equipment, when displayed on the display screens.

12.4.4 Data Handling

All real time data shall be stored in operation database within the SCADA Central Computer. The operation database shall store all data for one year period. The data which are necessary for reports and statistics shall be transmitted to a historic database. The historic database shall be designed for 10 years data storage period. After 10 years the data shall be compressed by a logarithmic algorithm.

Collected data shall constitute a historical archive, according to modalities to be defined during the design phase and approved by the Client.

12.5 Computing, Simulation & Prediction System for Structure Loads and Weather Simulation (CSP)

Please see document Management, Administration & Computer Simulation doc no. CG.10.00-P-RG-D-P-CG-00-00-00-00-01-A

12.6 Worksite Management System (WSMS)

Please see document Management, Administration & Computer Simulation doc no. CG.10.00-P-RG-D-P-CG-00-00-00-00-01-A

12.7 Bridge Management System

Please see document Management, Administration & Computer Simulation doc no. CG.10.00-P-RG-D-P-CG-00-00-00-00-01-A

12.8 Information & Coordination Management System

Please see document Management, Administration & Computer Simulation doc no. CG.10.00-P-RG-D-P-CG-00-00-00-00-01-A

12.9 Electronic Document Management System

Please see document Management, Administration & Computer Simulation doc no. CG.10.00-P-RG-D-P-CG-00-00-00-00-01-A

12.10 Structural Health Monitoring System

12.10.1 Introduction

The Structural Health Monitoring System (SHMS) shall be a sophisticated redundant set-up that shall provide the owner and operator with important information concerning structural behaviour and safety as well as information that will assist with operation and maintenance planning. The SHMS will also provide a valuable tool for investigating and trouble-shooting unforeseen problematic behaviour such as wind induced vibrations. The SHMS shall be in place prior to construction and shall be progressively brought online as the bridge is built, which will provide the constructor with important information during the erection stage concerning structural behaviour and safety.

The design needs to be developed alongside the design of the structure so that, when complete, the system monitors those areas that are critical and relevant. A number of critical areas may only become evident towards the end of the design process. The design may also develop from

completion of the design phase to completion of the construction phase so as to incorporate post-design technology advancement. Therefore details presented herewith represent the direction the design is taking but may not entirely represent the final design.

The SHMS shall be a stand-alone system that, in function, operates independently of other operation systems of the SCADA system. The SHMS shall display live data and triggered alert data (including seismic triggered alert data) to assist with bridge operation and maintenance. A log shall be provided with the alert interface for alert categorisation. The SHMS shall provide data in a database which can be accessed by other operation systems of the SCADA system. Data shall be received from on-site sensors as part of the SHMS network as well as from other components of the SCADA system.

For the purposes of installation and system operation, the SHMS component of the SCADA system shall include the measuring of all physical parameters that are identified for measurement as part of the project, except for measurement of rail and vehicle load. The measurement of rail and vehicle load using Weigh-in-Motion systems shall be included as part of the TMS component of the SCADA system. Total traffic load data shall be delivered to the SHMS for inclusion.

12.10.2 Monitoring Priorities

The SHMS is targeted at the following tasks as a priority:

- Monitoring of wind conditions during construction to confirm safe environment for construction works.
- Monitoring during construction to confirm assumptions for construction stages and structural behaviour in temporary erection conditions.
- Monitoring following construction to confirm final geometry and design assumptions.
- Monitoring of wind conditions and road conditions to confirm safe environment for traffic use of the structure.
- Monitoring of loads to confirm safety for traffic use of the structure.
- Monitoring to confirm bridge geometry and performance during regular loading events and extreme loading events.

- Monitoring position of tower foundations, anchor blocks and tie-down pier foundations to verify foundation movement and stability.
- Monitoring to provide data for future statistical analysis and review of design loading.
- Study of response of the bridge structure to wind, to confirm agreement with predictions during design and wind tunnel testing.
- Study of response of the bridge structure to rail and vehicle traffic, to confirm agreement with predictions during design.
- Study of response of the hangers to wind, to confirm agreement with predictions during design and wind tunnel testing and to very needs for additional damping to prevent the development of excessive aerodynamic effects.
- Study of response of the hangers to rail and vehicle traffic, to confirm acceptable vibration levels.
- Monitoring of structural response during seismic event.
- Rapid reporting of the bridge condition following seismic event or wind storm loading.
- Monitoring of stress variations for up-to-date fatigue life evaluation.
- Condition monitoring to assist effective maintenance programming, including expansion joint performance, buffer performance, tower Tuned Mass Damper performance, and road wear.
- Monitoring of internal environmental conditions to assist with effective control of the dehumidification system and to monitor for the development of abnormal conditions.

12.10.3 Reconciliation of Instrumentation

Each sensor that is installed provides data to a data channel, data which needs to be handled. The more data that is processed, the more extensive the system becomes. A number of risks exist with excessive data records including:

- The more data that is recorded, the greater the risk of data management problems with software and storage.

- The more data that is recorded, the more likely the amount of data becomes over-whelming, and consequently the system is at risk of not being used effectively for bridge operation.
- During critical events, a risk of data overload with subsequent system software breakdown.

It is therefore important that sensors are strategically located, only relevant data is displayed, and data is presented in an effective manner for bridge operation.

The tender specification lays out a comprehensive arrangement of sensors for monitoring of the structure. The arrangement focuses on general monitoring of the structural behaviour, structural condition, environmental conditions and load conditions, with sensors distributed in nodes that are evenly positioned around the structure. Thus the system established considers the overall structural performance. In service, most maintenance problems tend to be local problems. The preliminary design expands the capability of the SHMS proposed by the specification to include monitoring at a local level.

The arrangement of sensors presented in the tender specification and preliminary design has been reviewed and further developed to optimise the SHMS, and to include developments in technology since the submission of the preliminary design. The arrangement of sensors shall be reviewed continuously throughout the detailed design phase.

The following improvements have been identified to date:

- Repositioning of hanger accelerometers to monitor the longer "dynamically at-risk" hangers.
- Addition of hanger strain measurements to reliably monitor hanger loads and to provide data for hanger fatigue monitoring.
- Reduction of data channels allocated to main cable temperature readings in the primary SHMS data files, however data shall be monitored at all nominated locations and kept as separate data-files for future reference.
- Addition of nodes for measuring main cable stress using internally fed and surface-mounted strain gauges, to "de-risk" complete data loss due to sensor damage during construction and within service as well as to provide access to some main cable strain gauges for future maintenance.

- Relocation of end span wind stations to a position adjacent to tower legs to monitor wind turbulence around the tower legs, which can aggravate aerodynamic response of the nearby long hangers.
- Removal of excessive quantity of thermal measurements from the deck and tower to leave a more balanced arrangement.
- Readjustment of deck plate strain gauges for fatigue monitoring to beneath the wheel tracks of all lanes.
- Addition of fatigue monitoring adjacent to an expansion joint, where dynamic loading can be important.
- Inclusion of strain gauges to monitor other sensitive regions, including longitudinal deck beam to cross beam interface and diaphragm cope holes.
- Minor readjustment of sensors for monitoring general environmental conditions (air temperature, solar radiation and air pressure) for an improved installation.
- Readjustment and addition of tower leg strain gauges to monitor tower leg stresses both above and below the portals.
- Readjustment of tower portal strain gauges to monitor tower portal stresses adjacent to the legs where load effects are greatest.
- Readjustment and removal of deck accelerometers and inclinometers to provide data output that is more straightforward to understand than would be provided by the original configuration.
- Replacement of a number of road temperature sensors with road wear sensors.
- Addition of linear displacement sensors for monitoring of the tuned mass dampers in the towers.
- Addition of hydraulic pressure sensors and linear displacement sensors for monitoring of all of the buffers rather than only those at the towers.

12.10.4 System Components

The SHMS consists of:

- Permanently installed sensors and measuring devices.
- Data-loggers.
- On-structure Data-cabling.
- On-structure Power-cabling.
- Data-relay units.
- Data Acquisition and processing Units (local servers located on the structure) including temporary data storage.
- Uninterruptable Power Supply units.
- Brackets and local support structures for all on-structure equipment including weather protection, cooling, service lighting and other related equipment.
- Physical protection for all on-structure equipment including lightning finials.
- (Data communication system: all data shall be transferred via the WAN network).
- Mainframe server in SCADA.
- Data storage in SCADA.
- Operator access terminals and equipment.
- Portable SHMS equipment: sensors, data-loggers, data cabling, computers and equipment, and video system.
- Tectonic survey markers.
- Spare parts for maintenance of SHMS system.
- Tools to assist maintenance of SHMS system.

12.10.5 Sensors

The current proposed sensor array (which is still in development) consists of:

	number of locations		
	current design	*preliminary design*	*tender specification*
Wind speed and direction measurements	**38**	*38*	*30*
External relative humidity measurements	**5**	*4*	*4*
External air temperature measurements	**7**	*10*	*10*
Solar radiation measurements	**3**	*4*	*4*
Air pressure measurements	**4**	*4*	*4*
External surface humidity measurement	**2**	*2*	*2*
Coordinate measurements (including reference)	**55**	*55*	*60*
Road wear measurements	**8**	*0*	*0*
Road temperature measurements	**10**	*18*	*18*
Ice formation measurements	**2**	*2*	*0*
Rainfall measurements	**4**	*4*	*4*
Water veil measurements	**4**	*4*	*4*
Internal relative humidity measurements	**110**	*110*	*110*
Internal air temperature measurements	**66**	*60*	*60*
Internal surface humidity measurements	**36**	*36*	*36*
Acceleration measurements in 1-axis	**0**	*496*	*0*
Acceleration measurements in 2-axes	**64**	*44*	*44*
Acceleration measurements in 3-axes	**29**	*53*	*53*
Seismic high definition acceleration measurements in 3-axes	**12**	*12*	*12*
Static inclination measurements in 2-axes	**20**	*24*	*24*
Dynamic inclination measurements in 2-axes	**8**	*34*	*34*
Dynamic inclination measurements in 3-axes	**15**	*0*	*0*
Steel temperature measurements	**756**	*770*	*946*
Steel strain measurements	**1400**	*916*	*704*
Linear displacement measurements	**90**	*36*	*36*
Hydraulic pressure measurements	**36**	*24*	*24*
Concrete rebar corrosion measurements	**20**	*20*	*20*
Local ground settlement measurements	**10**	*10*	*10*
Ground pressure measurements	**6**	*6*	*6*
Ground interstitial pressure measurements	**10**	*10*	*10*
Tectonic survey benchmarks	**10**	*10*	*10*
Studs for potentiometer concrete corrosion monitoring	**20**	*20*	*20*
Acceleration measurements in 2-axes with portable equipment	**16**	*16*	*0*
Local video systems	**33**	*33*	*0*
TOTAL	**2909**	*2885*	*2299*

Rail load and vehicle load measurements shall form part of the TMS with data delivered to the SHMS as required.

12.10.6 Primary Hardware

The proposed data management system (which is still in development) consists of:

- On-structure Data Acquisition and processing Units (DAU): 15 units.
- In-SCADA Mainframe server: 2 units (one primary, one back-up).
- In-SCADA SHM Data store: 2 units (one primary, one back-up).

The DAUs shall be capable of storing a pre-defined duration of processed data in case of connection failure to the Mainframe Server. The DAUs shall also have a dedicated data buffer to facilitate processing of triggered alarms.

The DAUs shall be connected to the Mainframe server via a WAN network that shall support all data communication through the structure.

The Mainframe server shall have a dedicated data buffer to allow access to data from other components of the SCADA.

12.10.7 Power Supply

SHMS equipment is sensitive equipment. The equipment needs to be protected against power fluctuations.

Power shall be supplied to the SHMS from a dedicated power supply. The hardware shall be protected by power-surge fuse circuits.

Sockets to the power supply shall be unique so that only SHMS equipment can be attached. The sockets shall be placed in lockable cabinets.

All primary hardware to the SHM shall be fitted with Uninterruptable Power Supply (UPS).

On-structure SHMS equipment shall be earthed to the bridge which in turn shall be earthed to ground.

12.10.8 Sensor Connection to the Structure

All sensors shall be connected to the structure with appropriate mountings and booms that are designed for the factored design loading. The local mountings and booms shall be designed by the SHMS designers. Coordination with the bridge structural designers shall be required to design local strengthening for transfer of local loads into the primary structure.

12.10.9 Physical Protection

SHM equipment is delicate equipment. The equipment needs to be protected against accidental damage, particularly during construction.

All on-site instrumentation (sensors, loggers, DAUs and cabling) shall be durable and IP65 rated.

All on-site instrumentation (sensors, loggers, DAUs and cabling) shall be installed in protective housings connected firmly to the structure.

All external equipment shall be suitable for the harsh environmental conditions.

Equipment installed on booms shall be fitted with lightning protection.

12.10.10 Operation

The SHMS shall be a sophisticated monitoring system that shall provide key data from nearly 3000 sensors located strategically around the structure. Data quantity shall be vast, and as such effective data management routines shall be developed. The basic operation of the system shall be as far as practicable automatic, requiring minimal operator input. The system shall:

- record, condition and convert data to engineering units.
- process data required for engineering analysis, including rainflow counting, calculation of effective box and main cable temperatures, as well as rolling mean and gust wind speeds.
- create and store low definition data for historical record.
- respond to triggers, and create and store high definition data.
- detect and report sensor malfunction, and deactivate sensor data from malfunctioning sensors.
- display live data.
- include a facility for looking at data recorded from triggered alerts.
- provide a log of triggered alerts, with interface for assessment and categorisation.

Day-to-day operation of the system will be kept as simple as possible. The Mainframe server for the SHMS shall be located in the SCADA room. The SHMS shall be controlled from the Mainframe

server. A dedicated interface display shall continuously present key data in simple format. The operator is expected to investigate and respond to alerted triggers and sensor malfunctions.

Remote access to the Mainframe server and data store server, via a VNC interface (or similar) with user access and password protection, is under consideration. If remote access is adopted, a strategy for system control would be developed whereby initial access could be restricted to visual-only, and temporary system control could be implemented via SCADA operator approval.

Configuration of the SHMS system shall be controlled from the Mainframe server by a configuration interface.

All primary data-processing that is required by the SHMS, with the exception of processing listed below, shall be performed within each DAU. The Mainframe server shall process the following data:

- data received from other components of the SCADA system that require processing.
- total rainflow count data assembled from segmental rainflow count data.
- fatigue utilisations calculated from total rainflow count data.
- wind pressure data calculated from gust wind speeds, which shall be displayed against traffic load.
- alert on serviceability wind speed conditions.
- alert on loading conditions.

Each DAU will be provided with software that allows review of data stored on the DAU, live display of data that is recorded, and tools for maintenance. The DAUs shall be provided with monitors. The DAU software shall be both accessible at the unit as well as remotely from the Mainframe server. The DAUs will be capable of communicating with the Mainframe server as well as the other DAUs. It shall be possible to connect maintenance laptops to the DAUs and Mainframe server.

Event recognition and recording shall involve the sending and receiving of triggered alert signals between the DAUs and the Mainframe server. The alert shall be displayed on the live displays in the SCADA room. A facility shall also be created that emails and/or texts a list of users when nominated events are registered. DAUs shall create alert files that contain data preceding the alert and data following the alert. Thus the development of the event shall be recorded. The DAUs shall

contain a rolling buffer of high definition data to facilitate this process. The rolling buffer will be user definable.

The DAUs shall have data storage capability for 28 days (to be confirmed (TBC))- in case of connection breakdown with the Mainframe server. The first day of data contained on the temporary data-store shall be protected from being overwritten.

12.10.11 Interaction with SCADA

The SHMS shall interact with other components of the SCADA system.

Data shall be received from a number of components of the SCADA system as follows:

- total vehicle and traffic load on the bridge (from the TMS component) - every second.
- future predictions of wind and traffic (from the CSP component) - notionally every 30mins.

The SHMS shall not send any information to other components of the SCADA system. Data shall be available for other components to copy data from the SHMS data store.

12.10.12 Data Channel Grouping

For the purposes of configuration file management, data channels shall be grouped into families and called-up on displays by family.

For the purposes of alert data file efficiency, each data channel shall have assigned to it appropriate data channels that are to be recorded if that data channel is triggered. If numerous channels are triggered within the defined timeframe, all of the appropriate channels for recording shall be recorded in the same alert data file. The timescale of the file record shall be extended in accordance with the last trigger received.

12.10.13 Data File System

Data files shall be created by each of the DAUs. Filenames shall identify the DAU to which the data relates. Data shall not be assembled into a single file at the Mainframe server. Filenames shall also identify the time of file creation in the form of YYYYMMDD or YYYYMMDD-hhmmss as appropriate.

The following data file types shall be created:

- High-definition file (temporary)
- History file 1
- History file 2
- History file 3
- History file 4
- Alert file
- Seismic alert file
- Statistical data file
- Additional data file
- Rainflow count file.

History files shall contain maximum value, minimum value, mean value, point value, and standard deviation for all data channels. History files shall contain data covering user-defined timescales e.g. 1day, 7days, 1 month, 1 year. Data recorded in history files shall be based on user-defined sampling periods e.g. 1min, 1hour, 1day, 1month.

Alert and Seismic alert files shall contain point values recorded at the nominated alert sampling frequencies for data channels associated to the alert. Data contained in alert files shall represent user-defined time periods pre- and post-alert trigger.

Statistical data files shall contain all point value data recorded for statistical purposes (e.g. wind and traffic) with the required parameters.

Additional data files shall contain all point value data recorded for additional purposes (e.g. detailed temperature) with the required parameters.

Rainflow count files shall contain all rainflow count data for a user-defined period. Rainflow count files shall be added to a total count on the Mainframe server.

The Mainframe server shall create the following files:

- History file 1 for traffic load on bridge
- History file 2 for traffic load on bridge
- History file 3 for traffic load on bridge
- History file 4 for traffic load on bridge.

These history files shall be created from data received from the TMS component, and shall match the format of the main history files created by the DAUs.

The Mainframe server shall update the following files:

- Alert log.

Alert log files shall contain a list of all alerts, including time of alert, sensor alerted, trigger value exceeded, minimum value in alert file, maximum value in alert file, average value in alert file, standard deviation in alert file, alert file reference, and operator nominated condition of components that has alerted (taken from a condition log). Data shall be added to the alert log files by the operator, in response to the alert, including grouping of alerts, initial assessment of alerts (importance, relevance and severity), subsequent assessment of alerts (importance, relevance and severity), and date and time of change to data.

12.10.14 Other Operation Files

Other files required for operation of the SHMS, and created at the Mainframe server, shall include:

- Configuration file
- System configuration file
- Channel status file
- Alert association file
- Condition file.

Filenames shall identify the time of file creation/change in the form of YYYYMMDD or YYYYMMDD-hhmmss as appropriate.

Configuration files shall contain all data concerning configuration of the data recorded, including alert sampling rates, alert trigger levels, engineering limit levels, malfunctioning-indicator limit levels, and user-defined offset parameters. A single configuration file shall exist for all data channels. Every configuration file created shall be retained and stored on the SHMS data store.

System configuration files shall provide all general systems configuration data.

Channel status files shall report the status of the channel e.g. active, deactivated, malfunctioning.

Alert association files shall contain the association of data channels to be recorded in the event of a triggered alert to each data channel that is triggered.

Condition files report the assessed condition of the element monitored.

12.10.15 Data File Form

Data files shall be used by other components of the SCADA system. The SHMS needs to also be sufficiently flexible in architecture to allow channels to be added to the data files.

The data file structure shall be simple. Data files shall either be in text format or in database format (TBC). Data shall be presented in columns according to data channel. All data shall be time-stamped. Data files shall be compressed to minimise file size. Routines shall be developed for accessing and converting data from the primary data file format to text and database formats, for use by other components of the SCADA system. These routines shall also be available in a user-interface program.

12.10.16 Output Data Format

Data recorded by sensors is not necessarily in the format that is most useful for engineering analysis purposes. Data shall therefore be converted into a suitable format. Furthermore additional data channels shall be derived to present a collection of data in a format that is useful to the monitoring of the structure. Below is a list of engineering conversions and derived data channels required:

- Wind speed and direction measurements: derived as point value wind speed in 3-axes shall be converted to plan (mean and gust) wind speed, plan (gust) wind direction (relative to local bridge axis), vertical (mean and gust) wind speed component, and (gust) vertical angle of

wind speed (deg). Mean and gust values shall be based on rolling-average of user-defined time scales e.g. 600 seconds for mean and 1 second for gust. Units: wind speed in m/s and wind direction in deg.

- Internal and external dew point temperature measurements: to be calculated from local relative humidity and air temperature measurements. Units: deg C.
- Coordinate measurements: derived in latitude, longitude and ellipsoid height shall be converted to a cartesian coordinate system (for example UTM-form of coordinates) based on a local geoid, and zeroed to a reference position near to the bridge. Units: m.
- Road wear measurements: xx (TBC).
- Effective tower leg temperature measurements: to be calculated from local steel temperature measurements. Units: deg C.
- Effective roadway girder temperature measurements: to be calculated from local steel temperature measurements. Units: deg C.
- Effective railway girder temperature measurements: to be calculated from local steel temperature measurements. Units: deg C.
- Effective main cable temperature measurements: to be calculated from local steel temperature measurements. Units: deg C.
- Stress measurements: derived as strain shall be converted to stress. Units: MPa.
- Hanger force measurements: to be calculated from local hanger strain measurements. Units: kN.
- Main cable force measurements: to be calculated from local main cable strain measurements. Units: MN.
- Hydraulic pressure measurements: derived as pressure shall be converted to force. Units: kN.
- Orthotropic deck plate stress rainflow count measurements: to be calculated from nominated strain measurements. Strain fluctuations shall be converted to stress and processed into

number of fluctuations for each nominated stress range. Output: table of stress ranges and counts at each stress range. Units: MPa and Number of counts.

- Hanger stress rainflow count measurements: to be calculated from nominated strain measurements. Strain fluctuations shall be converted to stress and processed into number of fluctuations for each nominated stress range. Output: table of stress ranges and counts at each stress range. Units: MPa and Number of counts.
- Hanger force rainflow count measurements: to be calculated from nominated derived strain measurements. Strain fluctuations shall be converted to force and processed into number of fluctuations for each nominated force range. Output: table of force ranges and counts at each force range. Units: kN and Number of counts.
- Expansion joint movement rainflow count measurements: to be calculated from expansion joint linear displacement sensor. Linear displacement fluctuations shall be processed into number of fluctuations for each nominated displacement range. Output: table of displacement ranges and counts at each displacement range. Units: mm and Number of counts.

All other data shall be in recorded in standard units:

- Temperature: Units: deg C
- Relative humidity: Units: %relative humidity
- Solar radiation: Units: W/m2
- Air pressure: Units: mbar
- Rainfall: Units: mm/hr (TBC)
- Water veil: Units: l/hr (TBC)
- Ice formation: Units: xx (TBC)
- Acceleration: Units: g
- Inclination: Units: deg
- Buffer displacement: Units: mm

- Expansion joint displacement: Units: m
- Tuned-mass-damper displacement: Units: mm (TBC)
- Concrete rebar corrosion: micro-Amps (TBC)
- Ground settlement: mm (TBC)
- Ground pressure: Pa (TBC)
- Interstitial pressure: Pa (TBC).

12.10.17 Alert Definition

A system for drawing the operator's attention to certain readings is required in order to have an SHMS that can be used to maximum effectiveness. Trigger levels and protocols shall be established for data channels to initiate an alert of an event. A number of different events shall be targeted:

- Alert on sensor and hardware malfunction
- Alert on critical serviceability conditions
- Alert on critical strength conditions.

In addition, warning signals shall be triggered and logged, although data shall not be recorded, when values recorded approach within a defined range of the alert condition. Warning level and protocols shall be established for the following events:

- Warning on critical serviceability (and maintenance) conditions
- Warning on critical strength conditions.

Warnings and alerts shall be established for the following parameters:

- Deck level transverse wind speed (serviceability condition - to ensure safe passage of bridge).
- Deck level transverse wind pressure in combination with total traffic load (strength condition - to ensure safe structure).

- Relative humidity (serviceability condition - to ensure operation of dehumidification system).
- Steel temperature (serviceability condition - with comparison against dew point temperature to ensure operation of dehumidification system).
- Deck vertical position (serviceability condition - to ensure navigation channel clearance).
- Anchor block position (strength condition - to ensure stable anchor block).
- Tie-down pier position (strength condition - to ensure stable tie-down pier).
- Tower base position (strength condition - to ensure stable tower base).
- Hanger acceleration (serviceability condition - to ensure hanger stability).
- Deck acceleration (serviceability condition - to ensure deck stability).
- Main cable acceleration (serviceability condition - to ensure main cable stability).
- Tower acceleration (serviceability condition - to ensure tower stability).
- Tower tilt (serviceability condition - to ensure tower stability).
- Road temperature (serviceability condition - to ensure safe passage of bridge).
- Ice formation (serviceability condition - to ensure safe passage of bridge).
- Rainfall (serviceability condition - to ensure safe passage of bridge).
- Water veil (serviceability condition - to ensure safe passage of bridge).
- Road wear (serviceability condition - to ensure safe passage of bridge).
- Hanger force (strength condition - to ensure damage-free hanger).
- Main cable force (strength condition - to ensure damage-free main cable).
- Tower leg and portal stress (strength condition - to ensure damage-free tower).
- Tower base anchor bolt stress (strength condition - to ensure damage-free anchor bolt).
- Deck longitudinal box and cross-beam stress (strength condition - to ensure damage-free deck).

- Anchor block anchor bar stress (strength condition - to ensure damage-free anchor bar).
- Expansion joint displacement (strength condition - to ensure damage-free expansion joint).
- Buffer force and displacement (serviceability condition - to ensure functioning buffers).
- Tuned mass damper displacement (serviceability condition - to ensure functioning tuned mass dampers).
- Main cable to tower saddle displacement (strength condition - to ensure stable connection).
- Main cable to anchor block saddle displacement (strength condition - to ensure stable connection).
- Corrosion (serviceability condition - to ensure good condition of concrete).

In addition to the above alerts, a seismic alert shall be established based on the following parameters:

- Accelerations measured by the seismic accelerometers (based on a minimum number of triggered data channels within a specified timeframe).

The reliability of sensor data shall be reflected in the propensity of the sensor to generate false alarms. False alarms are those alarms associated with spurious signals that do not reflect the variation in the parameter measured. Spurious signals develop from external influences on the sensor system, which often are unpredictable. The SHMS design is being developed around appropriate technologies that minimise the development of spurious signals from external influences. For example, fibre optic sensors shall be used instead of electrical sensors where possible to eliminate the influence from electromagnetic field variation. However it may not be feasible to completely eliminate the generation of spurious signals, and due to the unpredictable nature of spurious signals it shall not be possible to indicate at the design stage the maximum expected percentage of false alarms that shall develop. However data algorithms shall be developed to compensate for predetermined signal variations that will be known to represent spurious signals.

12.10.18 Data Display

A vast amount of data will be acquired by the SHMS for various purposes. Effective data visualisation is important to ensure maximum effectiveness of the SHMS within the operation and maintenance of the structure. Data visualisation will vary by purpose. No single data visualisation strategy is appropriate for all of the data.

A variety of screens will be developed. A general overview screen will indicate the general status of sensors in any particular part of the bridge. The sensors shall be grouped by type at each location. A coloured status button will indicate the worst status of any sensor in the group in that location. When the status button is chosen a new screen will appear which gives more information concerning the group of sensors in the particular location. Other generic screens shall be created to show live data and status of sensors. The user will be able to choose which screens are visible on the monitors provided, although the general overview screen shall always be displayed on one monitor.

The generic screens will include:

- Display of internal environmental conditions in tabulated form.
- Display of nominated location(s) of wind conditions in form of rosettes and in numeric form.
- Display of external environmental (including wind) and road conditions in numeric form overlaid on general location on structure.
- Display of tower, deck, main cable, hanger, and anchor bar stresses, and hanger and main cable forces in numeric form overlaid on general location on structure.
- Display of tower, deck, main cable, anchor block, tower base, and tie-down pier acceleration and inclinations, display of tuned mass damper movement, and display of hanger accelerations in numeric form overlaid on general location on structure.
- Display of buffer parameters, expansion joint movement including total movement (with possibility to select to see total rainflow counts), and main cable movement relative to anchor block saddles and to tower saddles in numeric form overlaid on general location on structure.
- Display of ground parameters in numeric form overlaid on general location on structure.

- Display of fatigue utilisations (with possibility to select to see total rainflow counts) in numeric form overlaid on general location on structure.
- Display of overall bridge load conditions (gust wind pressure and total traffic load) in various graphic forms (both versus time, and total traffic load versus gust wind pressure) - data to include a period of previous readings.
- Display of buffer performance in graphic form (force versus displacement) - data to include a period of previous readings.
- Alert review screen.
- Seismic alert review screen.

12.10.19 Reports

Reports shall be produced automatically. The following automatic reports shall be produced:

- Weekly
- Monthly
- Yearly
- Immediately following seismic event

Other reports shall be produced at request:

- Load status from previous hour and including up-to-date future load predictions
- Fatigue status
- External environmental conditions status from previous hour and including up-to-date future prediction
- Maintenance status
- Log status

For each report the data for the default set of data shall be presented. It shall also be possible for the operator to select additional data to be added to the report.

12.10.20 Installation Philosophy

The SCADA building shall either be built and fitted out prior to construction of the bridge, or a temporary building shall be provided. The SHMS Mainframe server and SHMS data-store shall be installed and operational prior to construction of the bridge superstructure. The temporary weather stations established for the Works by the constructor shall be connected to the SHMS Mainframe server via wireless connection. SHMS data channels shall be activated on the SHMS Mainframe server at the earliest opportunity during construction.

On-structure SHMS equipment shall be installed, where possible, following section fabrication hot-works and prior to shipping to site. Installation of equipment whilst in the fabrication yard or holding depot has many purposes including:

- to create a safe working environment for the workforce.
- to create a controlled working environment for good quality installation.
- to minimise the presence of SHMS installation workforce on the site for improved site management.
- to record true stress states rather than derived stress states for improved accuracy of the SHMS.
- to expediate activation of sensors on the SHMS for improved construction phase monitoring.

The constructor shall need to sequence SHMS installation works into the construction programme.

Final positioning of sensors and equipment shall take into account the construction sequence, so as to optimise interaction of SHMS installation works with the main construction works, and therefore minimise disruption to the construction programme. Nodes of sensors shall be installed on the pre-fabricated sections and connected into data-relay units, which once connected to the network shall relay data to the DAUs. All SHMS equipment (sensors, loggers, DAUs, cabling, etc) shall be provided with protective housings to protect against damage from construction activities as well as to protect against damage during the service of the bridge. Cabling that passes between pre-fabricated sections shall be stored on reels within the pre-fabricated sections. In the towers reels shall be positioned so that the cables can be lowered down to the relevant connection point. Reels shall also be provided with a temporary protective housing to protect against damage from

construction works. Nodes of sensors shall be connected to the SHMS at the earliest opportunity in the bridge erection phase.

MAIN CABLE SENSOR INSTALLATION

Main cable internal distributed fibre optic sensors shall be durable and formed of equivalent diameter as the main cable wires. The fibre optic sensor shall be installed as one of the outer wires of the main cable strand, and shall therefore be installed during main cable strand formation. The fibre optic sensor shall be positioned as one of the top wires of the strand so that it sits on top of the group of wires as the strand passes over the saddle. The fibre optic sensor shall not be socketed with the structural wires.

Main cable sensors forming part of the local main cable monitoring nodes shall be installed on-site as the main cable is formed. Sensors shall be attached to the relevant strand once positioned. Each sensor shall be of discrete form. Cables feeding the sensors shall be durable and shall be fed out of the main cable over a length of several metres. Surface mounted sensors shall be installed in bespoke access points following main cable compaction and wrapping.

HANGER SENSOR INSTALLATION

Hangers shall be of parallel wire form with a protective coating. Hanger strain gauges shall be installed onto the outer wires of the hangers following application of protective coating. Bespoke access points shall be provided in the protective coating. The strain gauges shall be installed prior to hanger delivery to site, with the hanger stressed to known stress state under controlled conditions.

Hanger accelerometers shall be clamped to the hangers following application of the protective coating. The position shall be marked on the hanger prior to delivery to site. The accelerometers shall be installed on the hangers prior to lifting into position.

12.10.21 Structural Design Input

Data to be provided by the structural designers for effective operation of the SHMS includes:

- Serviceability limits
- Strength limits

- Appropriate trigger levels
- Predicted data readings for each stage of the erection operation
- Wind load versus traffic load limit
- Buffer performance (force versus displacement) curves.

12.10.22 System Operation Security

The SHMS will operate on a user account basis. Users will be assigned rights for performing various actions including:

- Changing screens on monitors in the SCADA
- Acknowledging alerts
- Accessing the alert log
- Modifying the alert log
- Modifying configuration files
- Accessing the DAUs
- Administrating the DAU software
- Administrating the Mainframe software
- Accessing the SHMS data-store
- Copying data from the SHMS data-store
- Modifying and deleting data on the SHMS data-store
- Allowing external users to take temporary control of the system.

Unique user accounts will be allocated to each individual. All user accounts shall be password protected. Passwords will expire every 4 weeks.

Only the system administrator will be able to access all areas of the SHMS, including source code for customised and tailor-made software. Read-write access to source code for customised and tailor-made software shall be provided.

12.10.23 Documentation

The following documentation shall be provided with the SHMS:

- Operation manual
- Maintenance manual
- System architecture guide
- Guide to the software source code
- Troubleshooting guide
- Sensor identification lookup sheets (name, location, etc)
- Alert diagnosis guide
- Quality Control documents.

12.10.24 Quality Control

Testing of sensors, cabling, hardware, software and data-processing routines shall be required at key stages within the project. All testing shall be accompanied by quality documentation. The following shall be required:

- All equipment shall be provided with operation certificates and warranty certificates.
- All sensors shall be provided with calibration certificates.
- All data processing and manipulation routines shall be independently tested and approved prior to delivery to site.
- All software shall be independently tested and approved prior to delivery to site. The testing process shall include a full simulation of the operation of the entire SHMS network.

- All components of the SHMS shall be independently tested for operation and approved before delivery for installation.
- All components of the SHMS shall be tested for operation immediately following installation and approved before delivery of the relevant structural component to site.
- All components of the SHMS shall be tested for operation following erection of the relevant structural component and approved.

All hardware (sensors, dataloggers, cables, data-relay units, DAUs, etc) shall be uniquely labelled and identified on the System Architecture Guide. Labels and markings shall be permanent. Cables shall be labelled at each end and every intermediate xxm (TBC). All labels shall be applied to the equipment before installation.

12.10.25 Copyright

The bridge owner shall be party to all copyright to source code of all customised and tailor-made software, and SHMS documentation.

12.10.26 Warranty

Warranty shall be provided for the following minimum periods:

- SHMS Mainframe server: xx (TBC) years
- SHMS Access terminals: xx (TBC) years
- SHMS Data store: xx (TBC) years
- DAU: xx (TBC) years
- Data relay-units: xx (TBC) years
- Data-cabling: xx (TBC) years
- Data loggers: xx (TBC) years
- Sensors: xx (TBC) years.

12.10.27 Provision for Future Maintenance

All SHMS equipment, with the exception of 'embedded' sensors, shall be installed such that they can be accessed for maintenance and replacement. Embedded sensors are those sensors that cannot be accessed due to physical restrictions. These include:

- Sensors embedded in the main cables
- Sensors embedded in the concrete foundations
- Tower base anchor base sensors.

The DAUs shall be built from hot-swept modules.

12.10.28 Provision for Future Expansion

The SHMS shall have provision for adding sensors. Provision shall be given for adding xx (TBC) sensors to each DAU. The DAU hardware shall be built so as to receive any type of sensor that is operational on the system at completion of the design. Data channels that are added shall be added as extra columns to the end of the datafiles. The SHMS Mainframe server software shall be capable of simple modification for the addition of extra DAUs.

12.10.29 Post-Design Technology Advancement

SHMS technologies are rapidly developing. One of the project aims is to adopt, where feasible, new technologies if they represent an improvement on technologies previously specified. This principle shall be retained but in conjunction with the following additional principles:

- New technologies shall only be adopted if they are demonstrated to be reliable.
- New technologies shall only be adopted if they are sufficiently established.
- New technologies shall only be adopted if they are demonstrated to be beneficial to the monitoring priorities.
- New technologies shall only be adopted if they are financially viable.
- New technologies shall only be adopted if they can be demonstrated to be compatible with the SHMS design.

- The process of adopting new technologies shall be performed only by the SHMS designers in conjunction with experts with sufficient experience to perform the work to the high standards required.

12.10.30 Development Risks

A number of development risks have been identified that shall be considered and developed into proposal during the design phase:

- Development of sufficiently durable fibre optic sensor to survive construction of in-service pressure from the main cable.
- Survival of internal main cable sensors - this is being de-risked by addition of other measurement techniques.
- Electro-magnetic interference and vagabonding currents from the power supply to the railway.

12.10.31 Associated Drawings

- CG1000-PAXDPCG-00SM000000-01-DWG: SHMS Bridge Overall Elevation
- CG1000-PPXDPCG-00SM000000-01-DWG: SHMS Bridge Overall Plan
- CG1000-PAXDPCG-00SM000000-02-DWG: SHMS Hangers and Main Cable
- CG1000-PDXDPCG-00SM000000-01A: SHM Flow Chart.

12.11 Control and Monitoring System (CMS)

All the technical installations shall be continuously monitored by the dedicated Computerized Control and Monitoring system (CMS).

This CMS for M&E installations shall collect data from the field via distributed local Intelligent Distributed Units (IDU), as well as be able to provide remote control functions to this field equipment. The following main functions shall be handled by the CMS:

- Operation of the electrical LV switchgear for power distribution system and generation of alarms in case of failure in the monitored circuits

- Operation of road lighting and generation of alarms in case of failure in lighting sections
- Monitoring of all electrically operated mechanical systems and generation of alarms in case of failures in their function

Furthermore, the CMS system shall store operation and monitoring data in a system database(s) for at least 1 year and generate reports, when requested.

The system will be connected in form of open ring, but operated as a radial system with possibility of reconfiguration in case of failure in one of the radials.

The CMS system shall collect and monitor data from the following M&E systems:

1 Power Supply and Distribution System (PMS)

2 Roadway Lighting System

3 Aircraft warning Light System

4 Navigation warning light

7 Drainage System

8 Technical Areas Lighting

9 Fire detection

10 LV substations.

The system shall have an intelligent distributed unit (IDU) located in each location where switchboards are located. The communication to these IDU's shall be carried out through Bridge Area Network.

Information collected or calculated by the CMS shall be accessible for the overall SCADA and management systems.

12.12 PMS

Monitoring and control of the power supply and distribution systems for the bridge shall be performed by a separate system named Power Management System (PMS).

The PMS shall operate the medium-voltage power supply system as a redundant system consisting of:

- Western primary electrical substation
- Eastern primary electrical substation
- Local distribution substations along the fixed link.

The power system shall be an automatic control system which provides network management in order to:

- Monitor presence of voltage in both possible feeders and choose the preferred feeder
- Choose the most economically preferable configuration and configure the system via remote control of switching equipment in the substations
- Monitor operation of all radials and detect failures
- Reconfigure the system in case of a failure in one or more radials.

All the switchgear shall provide the following output signals wired to an external terminal row for data capture of PMS:

a) Position (On/Off) for breakers and switches

b) Earth/phase fault current indicators for cable feeders

c) Voltage indication on cable feeders

d) Alarm trip from circuit breaker relay

e) Selection position of remote/local control

f) Current measurement in transformer feeder (4-20 mA)

g) Current & voltage measurements on busbar sections (4-20 mA).

12.13 Safety System (SSS)

12.13.1 General

The Bridge shall be equipped with an efficient system for safety related monitoring of all suspicious events related to the road/railway traffic and events in approach areas to Bridge on land, air and surrounding waters.

The Safety Systems (SSS) shall comprise of supply and installation of one or more computerised surveillance systems which are developed for protection of the Bridge against intrusion, sabotage and terrorism. The system contains of the following sub-systems:

- Anti-intrusion system
- Anti-sabotage system
- Anti-terrorism system.

Risks from an eventual terroristic attack or sabotage attempts shall be evaluated and be used as a basis for design of the safety and surveillance systems for the Bridge.

The aim of the safety and surveillance system(s) is that to preserve its structural and operative integrity, i.e. ensure protection to the Bridge itself, to users, to approaching or transiting vehicles, to technological infrastructures, to environment, by performing actions established through anti-sabotage risk studies.

On the basis of preliminary studies specified in CGC F.06.01 the following main functions shall be covered:

- Supervising/avoiding access to sensible/critical areas, here included construction sites, also by means of technologies and automatic systems of detection and identification of suspect objects or situations.
- Detecting dangerous/illegal products/substances (explosives, radioactive material, …).
- Monitoring the behavior of approaching/transiting vehicles, eventually with the use of automatic identification systems able to detect suspect movements, even if performed in different times.

- Detecting and trailing automatically small and fast means at low high above the sea level, as well as traces of airplanes, choppers, missiles and inflatable boats.
- Notifying alarms/emergencies.
- Detecting standing vehicles.
- Detecting floating objects close to the structure.
- Collecting, by means of adequate devices and interfaces, signals of accidents and suspect activities.
- Collecting preventive information related to means used for freight transport.

In particular, monitoring, collection and elaboration of all data necessary to produce even complex analysis shall be provided, in order to detect anomalies, inconsistencies, etc.

Alarm signals due to intrusion or sabotage shall be notified to the system in real time, and immediately communicated to the operator. All signals shall be adequately recorded, together with the related information on position, date and time.

Due to the general safety need of all transportation systems, the General Contractor shall adapt to possible national (European) safety standards and guarantee the information exchange and coordination with other safety institution and managers of transportation infrastructures.

Nonetheless the General Contractor shall collect all indications by the side of the Client and of the Institutions in charge of anti-terrorist and anti-sabotage activities; the proposed solutions shall undergo approval by the Client.

Surveillance against sabotage and terrorism is a critical function. Quality, accurateness, immediateness and continuity in data and images acquisition and elaboration, alacrity in signaling the alarms are essential characteristics. A meaningful contribute to the above-stated aspects shall be given by the quality and reliability of radio transmissions operated through the TETRA system.

12.13.2 Anti-Intrusion System

The Intrusion Detection System shall cover protection of the Bridge structures against unauthorised access and consist e.g. of:

1. Intrusion detection on land

   - Intrusion detection sensors in approach areas to the Bridge construction from land side
   - CCTV based intrusion detection at all approach places on the Bridge and under the Bridge.

2. Intrusion detection along the bridge

   - Access control system for all doors and openings in the Bridge construction, which may be accessed by potential intruders
   - CCTV based intrusion system for detection of all suspicious persons. This function shall be partly covered by CCTV cameras used for the Traffic Management System (TMS).

12.13.3 Anti-sabotage/Anti-terrorism System

The Bridge shall be equipped with Anti-sabotage/Anti-terrorism systems, which detect automatically the following security related events:

a) Objects floating under the bridge which are larger than 1x1 m;

b) New objects appearing on land within the Bridge safety area;

c) Any movement of objects within the Bridge safety area on land and at the sea;

d) Suspicious Vehicles

   - Vehicles moving slowly (speed less than 50km/h)
   - Vehicles accessing service roads
   - Vehicles accessing emergency lanes.

e) Access to the Bridge (Intrusion Detection System)

Anti-sabotage and Anti-terrorism System shall be based on a Video Motion Detection System transforming CCTV pictures into a tracking and detection system based on analysis of video images within the detection field.

The detailed design of the sub-systems shall be based on security risk study which will cover:

- Definition and analysis of risk scenarios
- Analysis of sufficiency of the proposed prevention methods
- Analysis of times for detection of security events and maximum response times
- Other risks.

12.13.4 CCTV Surveillance System

In general CCTV based surveillance equipment shall be installed along the Bridge and in all the places where the general security can be affected.

The resolution capacity of the system shall be defined accordingly to the lighting system performances. The cameras shall be integrated with anti-terrorism/anti-sabotage functions like “Slow Motion detection and Slow Down detection”.

The cameras shall also allow the object identification and the advice through acoustical or lighting signals the appointed personnel.

The distance of the cameras shall be fixed at 250 m, maximum, on both side of the carriageway. A part of these CCTV cameras shall be used for Traffic Management System (TMS) functions.

Referring to the anti-sabotage analysis and studies, all the access doors and gates to the Bridge, or unauthorized areas access (i.e. internal volumes) and all fences protecting the Bridge areas as well as all the critical and “Sensible Points”, shall be provided with an efficient surveillance system.

This system shall be designed and realized as per CEI 79 standards.

13 Communication Systems

The purpose of the Communication Systems Works is to establish radio, data and telephone communication for the management of operation, maintenance and emergency services of the Bridge, Control Centre, Toll stations and other relevant buildings within the area bounded by the Toll Station and the Control Centre

The Communications Works cover establishing of reliable Communications on and inside the Bridge and relevant buildings in the area and include the following systems:

- Data Communication Network
- Radio Communication Network
- Telephone System
- Emergency telephones.

13.1 Assumptions

The following systems are not part of these works:

- Communications facilities during construction of the Bridge
- Public mobile telephone communication systems.

13.2 General

The communications systems shall be designed using state of the art digital technology in order to ensure flexibility and maximum lifetime of the equipment.

Other key criteria for the design of the systems are:

- Redundancy and minimal convergence time
- Limited congestion
- Appropriate modularity
- Sufficient and scalable bandwidth
- High availability
- High manageability
- Industrial Ethernet level.

13.3 Communications and Transmission Systems

The communication and transmission system shall provide data communication facilities and functionality for data transactions related to the bridge environment and surrounding areas.

The communication and transmission infrastructure shall support the following systems:

- Radio communication (RCOM)
- Telephones (TEL)
- Emergency telephones (ETEL) (S.O.S Colonnine stations)
- Control and Monitoring system for technical plants
- Control Room facilities
- Control and Monitoring systems for road traffic and anti-sabotage protection; and

13.3.1 Network Concepts

The network sections are grouped in different categories:

- Data collection LANs interconnected to the
- Bridge Area Network (BAN) (Consisting of the network in bridge girders and towers which is connected to the
- Wide Area Network (WAN) running along the highway on each side of the Bridge.
- All communication on the BAN (Bridge Area Network) is relayed to the Control Centre LAN (Local Area Network) and distributed to the relevant nodes.

The network sections contain several of the below items:

- Copper Cabling Systems
- Fibre Optic Cable Systems
- Transmission Systems
- Network Management System

- Interfacing to the existing communication systems.

DATA COLLECTION LANS

The Data collection LANs interface are a switched 10/100 Mbit/s RJ45/8 Ethernet port.

TOWER AND BRIDGE AREA NETWORK (BRIDGE DECK)

The Tower and girder (bridge) deck backbone shall be designed to support and transfer a minimum of 1 (one) Gbit/s with the option of 10 Gbit/s. An alternative is to create "trunked" channels by using more fibre optic cables via switch technologies shall be considered during the design phase (Ethernet channel/trunks or equivalent).

The figure below shows an example of the backbone communication and transmission equipment design:

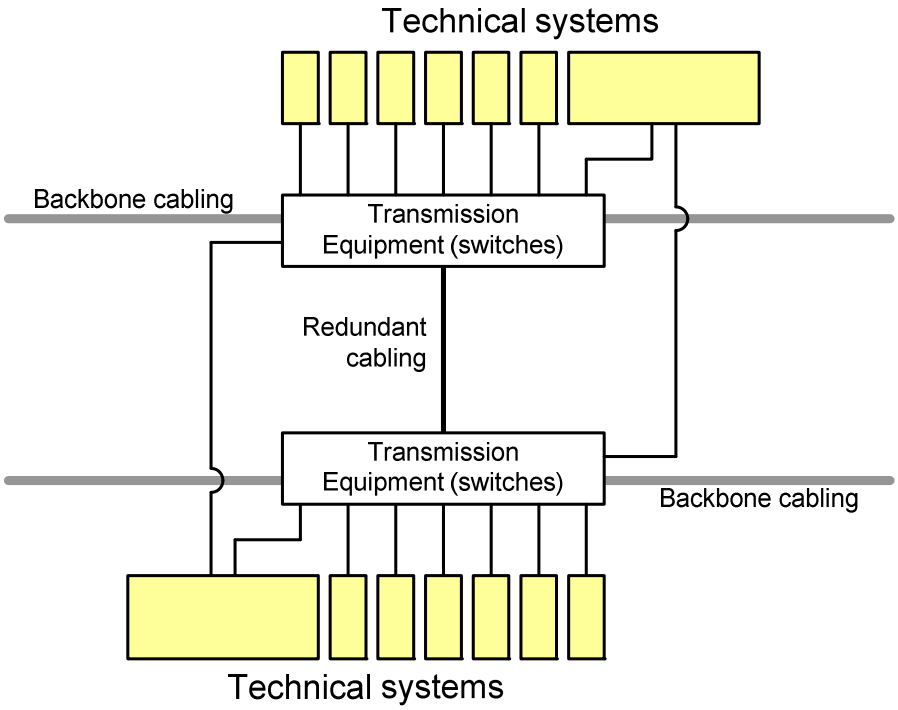

Figure 13.1 Example of the backbone communication and transmission equipment design

WIDE AREA NETWORK (WAN)

The Wide Area Network shall be installed in separate cableways. The backbone should be designed to support a minimum of 1 (one) Gbit/s with the option of 10 Gbit/s.

BRIDGE CONTROL ROOM

Following is assumed in the design of the LAN in the Control Centre:

- Equipment and cabling redundancy.
- Tier: Minimum type 2 (redundant equipment).
- LAN cabling:
- EN50173 and EN 50174, latest versions with all amendments, addenda and corrigenda; and
- TIA/EIA-606-A or equivalent.

13.3.2 Technical Specifications

CABLING REQUIREMENTS, FIBRE

The fibre optic network cabling shall comply with the following standards:

- ITU-T G.652 (Characteristics of a single-mode optical fibre and cable), latest version with all amendments, addenda and corrigenda.

Fibre optic cables shall be routed to the following locations:

- Bridge deck (girder)
- Along the highway
- In the Towers
- In the Bridge Control Centre
- In the anchor blocks.

CABLING REQUIREMENTS, COPPER

The copper cabling (PDS) shall comply with:

- EN 50173 (Generic cabling systems), latest version with all amendments, addenda and corrigenda.
- EN 50174 (Cabling installation), latest version with all amendments, addenda and corrigenda.

Shielded cabling shall be used.

SPECIAL REQUIREMENTS FOR CABLING

Special requirements:

- PDS Copper cabling has to be certified (manufacturer)
- PDS copper cabling shall comply to TIA/EIA 568-B.1, addendum 6.

COMMUNICATION AND TRANSMISSION EQUIPMENT

All switches shall be connected to the bridges uninterruptible power supply system.

Time to recover and to use an alternative route shall be less than two seconds from any port (from blocking/disabled to forwarding mode) in the network to any other port regardless of link recovery protocol (spanning-tree/rapid-spanning tree/mesh protocol).

The switches shall:

- be categorised as "newest technology" (shall not be on end-of-life)..
- be designed and manufactured to withstand the local conditions in the Bridge without to be installed in air-conditioned rooms or shielded EMC environment.
- support the LSS dual NIC redundant equipment, thus the fail-over links have a very limited convergence time (eventually supporting functionality as "port fast" or similar technology).
- support dynamic VLAN distribution over the individual switches.
- support link aggregation.

- be configured with a VLAN based switched environment with Quality of Service functionality (In the case of data communication between VLANs, the routing shall be based on the router in question situated in the Bridge Control centre).
- have a maximum response time from any port to any other port in the network (LAN and WAN) of 0.2 sec; and
- support an automatic configuration roll-out system for switches.

The switches shall comply with:

- IEEE 802.3
- IEEE 802.2
- IEEE 802.1D
- IEEE 802.1Q
- IEEE 802.1w
- IEEE 802.1s
- IEEE 802.3ad
- IEEE 802.3x
- IEEE 802.3af (where necessary)
- SNMP v1, v2 and v3
- HTML and telnet management.

Additionally the switches shall have:

Auto-sensing 10/100/1000 Mbps (IEEE 802.3 Type 10Base-T, 802.3u Type 100Base-TX and 802.3ab Type 1000Base-T) RJ45/8, Auto-MDIX and both half and full duplex transmission.

Minimum of 1000 Mbit/s (1 Gbit/s) fibre optics connectors, and connectors of type: GBIC or mini-GBIC.

13.3.3 Management of Communication Systems

To provide management and administration for the communication and transmission infrastructure software systems for maintenance and operations shall be included. The following management systems including the necessary hardware and software shall be provided:

- System for monitoring and control of the IT infrastructure for cabling and communication and transmission equipment.
- Telecommunications Management System for radio and telephone systems.

13.4 Radio Communication System

13.4.1 Assumptions

It is assumed that the radio communication system is only for the Operation & Maintenance staff of the Bridge.

Further, it is assumed that Police, Rescue and other emergency services have their own radio communication systems and that their respective technical organisations shall provide the necessary radio coverage.

Further it is assumed that all railway signalling and radio communication is not in the scope for COWI, and that design and planning hereof is done by the railway operator.

13.4.2 Functional Specifications

The radio communication system shall provide two way wireless communications for the use of the Bridge's operation and maintenance personnel.

Radio communication facilities shall be established to cover the Bridge deck and access roads including the road and the area around the Control Centre building and Toll Station.

Further, there shall be established radio coverage inside the buildings as well as inside the bridge girders, the towers and the anchor blocks

The radio system shall provide voice and low-speed data communication with full privacy between mobile/hand held radios and the operators in the Control Centre of the Bridge. Direct

communication between handheld radios or mobile radios shall also be possible. Broadcast calls, group calls in predefined groups and in dynamic groups shall be possible.

Further, it shall be possible to patch telephone calls to and from the fixed telephone system (PBX) in the control centre building and also to patch calls to and from the PSTN.

Real time information about the geographical position of a hand held or mobile radio units shall be transmitted to the operator in the Control Centre.

A Network Management System for the TETRA Communication System shall be supplied. The system shall provide possibility to remotely monitor and configure the communication switch and the base stations.

13.4.3 Technical Specifications

The radio communication system shall provide adequate coverage to ensure satisfactory two way radio communication (adequate S/N and intelligible speech quality) on more than 95 % of the specified coverage area.

The 5 % of the area where it is acceptable that the requirements are not fulfilled shall not constitute a continuous area but shall be small areas far away from the antenna systems or areas in the shadow of components of the bridge constructions.

The radio communication equipment shall be highly reliable and the system shall be designed such that the availability shall be at least 99.98 %.

The radio system shall be based on TETRA: TErrestrial Trunked RAdio as specified by ETSI. It is assumed that frequencies shall be allocated by the frequency management authorities of Italy.

Radio coverage of the outside areas shall be provided from antennas placed in the height of 25-30 m on antenna masts located on each land site of the Bridge.

Base stations shall be located in equipment rooms. The antenna system for coverage of the bridge girders, towers and anchor blocks shall consist of leaky coaxial cables combined with discrete antennas where practicable.

The communication switch shall be located in the equipment room of the Control Centre. The operators console shall be located in the control room.

All the base stations and the communication switch shall be connected to the WAN with TCP/IP interface.

The position of the radio units in the outside areas shall be established with GPS receivers connected to the radio unit. Inside the confined area of the Bridge it is not possible to use GPS receiver, therefore, tagging transmitters or similar technology are used.

It shall be possible to identify the position of the radio unit within an accuracy of approximately 100 m.

13.5 Telephone System

13.5.1 Functional Specification

A telephone system shall be provided in order to establish voice communication between the users in the bridge deck, the towers, substations, equipment shelters, the Control Centre, the Toll Station and the Public Switched Telephone Network (PSTN), etc.

The telephone system comprises the switch and peripherals such as telephone sets and fax machines. Remote control and diagnostics shall be included.

As a minimum the following user facilities shall be available:

- Voice mail and voice response
- Redial last number
- Abbreviated dialling
- Call pickup
- Call forwarding
- Automatic call back
- Direct inward dialling
- Direct outward dialling
- Call detail recording

- Blocking of selected prefixes and numbers.

The telephone sets shall be provided with display and hands-free operation and option for connection of a head-set.

13.5.2 Technical Specifications

The telephone system shall be based on Voice over Internet Protocol (VoIP) (IP-telephony). Telephone sets shall be connected to the LAN (Ethernet) by means of RJ 45 connectors.

The gateway to the PSTN shall comply with the requirements of the public telecom service provider.

13.5.3 Emergency Telephones

Emergency telephones (S.O.S. Colonnine) shall be located approximately each 500 m on both sides of the bridge deck. The telephones shall provide communication with the Control Room. The telephones shall be of the same type as used along the highways in Italy, and be suitable for use in the noisy environment of the road.

The telephone shall be illuminated with a built-in lamp, and clearly marked with the text: "Soccorso Meccanico, Sanitario e Polizia".

Further, the telephone shall be marked with operating instructions in four languages: Italian, English, French and German.

It shall be possible to identify the telephone that has been activated. Further, the nearby CCTV camera shall be automatically activated and the image presented to the operator in the control room.

The emergency telephones shall be provided with an IP-interface box and connected to the data communication network.

14 Dehumidification System

14.1 General

The dehumidification system shall be installed to avoid the corrosion of the steel in the following zones:

- The suspended deck (road and railway girders and terminal structures)
- The anchor block chambers
- The tower saddles
- The main cables
- The towers

The design and the solutions to be adopted aim to reduce the energy consumption and the life cycle cost (LCC), also providing the blowing of the de-humidified air into the main cables by using air booster/injection fans.

The dehumidification systems shall be designed to allow easy and efficient maintenance avoiding any kind of interference with the steel structures.

The dehumidification system shall be installed in areas suitable for access through hatches to facilitate maintenance or replacement.

Use of air ducts shall be reduced as much as possible.

14.1 Design Conditions

The design of the dehumidification systems shall be based on the following ambient conditions:

- Maximum air temperature +40 °C
- Minimum air temperature 3 °C
- Average air temperature +18.1 °C
- Maximum air humidity 0,0188 kg water vapour/kg air

- Atmospheric air pressure 101.3 kPa.
- Maximum internal air temperature +60 °C.

The ambient conditions shall be assumed to fluctuate within a 12 hour period as follows:

- Temperature: +15 °C or -15 °C
- Atmospheric air pressure: ±2.5 kPa.

14.2 Design Requirements

14.2.1 General

The design of the dehumidification system must be able to fulfil the following general requirements:

- Reliable operation and safety of personnel.
- Prevention of damage due to the saliferous maritime (salt fog) and climatic conditions, vibrations, lightning and damage due to corrosion and deterioration.
- Ease of inspection and maintenance.
- Ease and clarity of operation.
- Freedom from undue vibration and noise.
- Immunity against electromagnetic disturbances.
- Exclusion of birds, insects etc.
- Service life requirements for both mechanical and electrical parts of the dehumidification system shall be minimum 25 years.

14.2.2 Functional Requirements

The design of the dehumidification system must be able to fulfil the following requirements inside the steel bridge structure:

- Max 50% relative air humidity within the 24 hours.

- Relative air humidity max 40 % yearly average (operation set point max 40%).
- Dehumidifier capacities:
  - Dehumidification sections without make-up air for main cables: Min capacity 0.2 g/hour per m^3 dehumidified structure volume.
  - Dehumidification sections with make-up air for main cables: Min capacity 0.5 g/hour per m^3 dehumidified structure volume.
- Circulating air flow in bridge:
  - Min 2 times per 24 hours for girders, terminal structures and anchorage chambers.
  - Min 2 times per 24 hours for towers and saddles.
  - Min 24 times per 24 hours for main cables.
- Main cables:
  - Distance between injection points: Max 400 m corresponding to airtight cables.
  - Air pressure at injection points: Max 2 kPa.
- The machinery of the dehumidification plant shall be placed on vibration isolators.
- The friction loss of the ductwork shall not exceed: 1 Pa/m.
- The air velocity in the ducts shall not exceed: 6 m/s.
- The air velocity in the air intake shall not exceed: 2.5 m/s.
- The working load/operation range ratio of the components shall not exceed: 75%.
- The functional behaviour of the dehumidification systems shall be monitored continuously by means of instrumentation as follows. Signals shall be connected to and monitored from a monitoring system (SCADA):
  - Relative air humidity
  - Pressure
  - Temperature

- Velocity (air flow).

15 Water Distribution System (Fire Fighting and Washing System)

15.1 Purpose

This system shall be designed for the pressurized water distribution for the following purposes:

- Fire fighting on bridge and towers (Fire hydrant system)
- Washing system for steel structures.

15.2 Norms and Standards

Following norms and standards will be used when applicable.

EN 12845:2004 + A2:2009 Installazioni Fisse antincendio – Sistemi automatici a sprinkler – Progettazione, installazione e manutenzione; Fixed fire fighting systems - Automatic sprinkler systems - Design, installation and maintenance.

UNI 11292 Locali destinati ad ospitare unità di pompaggio per impianti antincendio. Caratteristiche costruttive e funzionali; Pumping station technical rooms for Fire fighting – Functional and constructive characteristics;

UNI 10779 Impianto di estinzione incendi, Reti di idranti, Progettazione, installazione ed esercizo; Fire fighting equipment, Hydrant systems - Design, installation and operation.

Exceptions to the above requirements are stated in the following sections.

15.3 Design Principles and Redundancy

15.3.1 Pump Station

A pumping station shall be located at the base of each tower for supply of water to the fire and washing main systems on bridge and tower.

Different independent water systems are in play. Two systems dedicated for each tower and two systems for bridge.

The fire fighting capacity is strictly connected with risk of fire event evaluated as part of Operational Risk Analysis.

The pump stations shall be connected to water reservoirs. Water reservoirs which are filed from the public water network and shall have a minimum capacity for one hour of continuous fire fighting. The pump stations shall be designed in accordance to EN 12845 and UNI 11292 standard.

The fire hydrant system shall be fully redundant and each pumping station shall for each system be equipped with two fire pumps, each one with 100% of flow capacity. A jockey pump shall be installed to maintain the operation pressure at all time.

The electrical power supply for the pump stations shall be realized by using a dedicated "city" line electrical supply and by using a diesel pump with.

The design of pumps electrical supply is including a fail safe automatic by-pass.

The Fire Fighting design proposal shall be submitted to the Fire Department for approval.

15.3.2 Water Distribution

BRIDGE

The fire distribution pipe for the bridge are placed on both sides of the railway girder. The fire mains are a wet system permantly prezurized and cross connected at the bridge feeting points in order to create a ring system which allow for line partition for maintenance purposes. Sectioning valves shall be located every 500 m.

The fire mains are connected to hydrants placed at the road girder. The distance between the hydrants is max. 90 m.

The hydrants shall serve both the railway girder and the adjacent road girder.

Water for washing of steel structures shall be from flush valves connected to the pipe mains. Valves shall be located along one of the railway sidewalk in the same location as fire hydrants. The valves shall be for for connection to water tanks on the bridge gantry.

TOWERS

A fire riser main in each tower leg shall be connected to fire hydrants located at each cross beam.

The water to the tower shall be supplied from the pump station located on ground site near the tower base.

Water for washing of steel structures shall be from flush valves connected to the pipe main. Flush valves shall be located inside of the towers at each gantry access door.

The valves shall be for for connection to water tanks on the tower gantry.

15.4 Design Basis

15.4.1 Fire Hydrants

FLOW

The flow rate for the horizontal fire mains on bridge shall not be required to exceed 2.000 l/min.

- 2,000 l/min (120 m^3/hour or 33 l/sec.)

Hydraulic calculations and pipe sizes for the bridge shall be based on providing 1.000 l/min at each of the two most remote fire hydrants on one of the two horizontal mains.

The flow rate for the fire riser mains in the towers shall not be required to exceed 300 l/min.

- 300 l/min (18 m^3/hour or 5 l/sec.)

Hydraulic calculations and pipe sizes for the towers shall be based on providing 300 l/min at the most remote fire hydrant in the top cross beam.

Minimum flow required from each fire hydrant:

- 1.000 l/min (60 m^3/hour or 16 l/sec.) - On the bridge
- 300 l/min (18 m^3/hour or 5 l/sec.) - In the towers.

PRESSURE

For the fire hydrants, the minimum residual pressure shall be required to 6,9 bar (g) for the bridge and 4 bar (g) for the towers.

- 6,9 bar (g) (residual pressure for the bridge fire hydrant)
- 4 bar (g) (residual pressure for the tower fire hydrant).

The pressure requirement shall be taken as pressure limitation to serve two fire hydrants simultaneously on the bridge.

15.4.2 Wash System

FLOW

Minimum flow requirement for each wash valve shall be required to:

- 125 l/min (2,1 l/sec.)

PRESSURE

For the wash valves connected to the fire mains pressure reducing shall be controlled to max.

- 4 - 10 bar

15.4.3 Frost Protection

The frost protection of the systems shall be achieved as follows:

1 The horizontal fire mains on bridge will not be insulated and heat traced. In case of temperatures below the freezing point a small flow in the pipes will prevent possible freezing. The water used will be lead back to the water reservoirs and circulated to the mains.

2 The steady water in branch off connections for fire hydrants and wash valves will not be able to circulate. The branch off connections shall be insulated and heat traced.

3 The fire riser mains in the tower shall not be frost protected.

15.4.4 Pipe Material

In order to reduce the weight GRE (Glassfiber Reinforced Epoxy) pipes are proposed as fire main material on the bridge.

In the towers will the fire riser mains located inside the towers be galvanised steel pipes rated for high pressure.

16 Drainage

16.1 Purpose

The purpose of the drainage system is to collect polluted water from the bridge and treat it at land based facilities before discharge to the sea. Polluted water is defined as first flush from a rain event.

Secondly the drainage system at the bridge shall be provided with overflow for storm water in order to better control surcharge of the drainage system at the bridge.

Drainage shall be achieved by gravity.

16.2 Design Basis

16.2.1 Rain Intensity (First Flush)

Table 16.1 First flush Design intensity given by SdM (Letter 28 MAG. 2010; 0512)

	Rain volume [mm]	Rain duration [min]	Rain intensity [mm/hr]
Design basis: ~ "First flush principle"	5	15	20

.

16.2.2 Pipe Material

In order to reduce the weight GRE (Glassfiber Reinforced Epoxy) pipes are proposed as drain pipe material. The GRP has very good corrosion behaviour and is relatively easy to connect inside the girders.

16.2.3 Pipe Roughness

The pipe roughness used for GRE is 1.5 mm. This is on the conservative side of what that can be expected during normal condition, but allows for some internal sedimentation.

16.2.4 Slopes

The design slope towards Calabria is 0.85 %.

The design slope towards Sicily is 1.5 %.

16.2.5 Spacing of Gullies

Gullies shall be spaced every 15 meters.

16.2.6 Oil and Petrol Separators

Oil/petrol separation shall comply with EN 858-1:2002 and EN 858-2:2003, Class I separators.

16.2.7 Sand Trap

The sand trap shall be designed to optimal conditions during the maximum design peak flow.

The minimum sand grain size to be settled is 0.5 mm.

16.2.8 Reception Chambers

Reception chambers in connection with sand trap shall be designed in order to accommodate the large vertical drop from the bridge deck to ground level.

16.2.9 Retention Reservoirs

The reservoir shall be designed to even out the incoming flow to the oil and petrol separator thus maximizing the amount of drain water being treated before discharge to the sea.

The storage volume will therefore exceed the theoretically needed in order to even out the design peak flow from the bridge drainage systems. Overflow from reservoirs (bypass of oil and petrol separators) is aimed to happen less then every 100 year.

16.2.10 Movement of Girders

The drainage collection pipes system shall be provided with provisions to accommodate the maximum movement between bridge elements.

16.2.11 Outlets to Sea

The outlet to sea is defined to discharge the clean rain water and there are no maximum discharge requirements for outlets to sea.

17 Access Facilities

17.1 General

The following are requested to be supplied:

- N° 2 independent elevators for each leg of the towers, total N° 8 elevators. Lifting speed no less than 3 m/s.
- Climbing and Travelling Gantries for tower legs maintenance.
- Travelling aerial Platform for Cables maintenance and inspection.

The 2 independent elevators for each leg shall guarantee the following:

- Redundancy of the system.
- Differentiated utilization: i.e. one elevator can operate between the ground floor and the second cross beam (roughly at 150 m. elevation) while the other elevator shall operate between the second cross beam and the top of the tower.

Please also see Technical Design Report – Secondary Structures document number: CG.10.00 P RX D P CG S5 00 00 00 00 01.

17.2 Maintenance Platforms etc.

Pending.

18 Interfaces

18.1 External Interfaces

A number of the E&M systems shall be connected to facilities which either are provided by the local utilities, or will continue outside the present contract limits.

The interfaces must be identified as early as possible in the design.

18.2 Internal Interfaces

A number of the E&M systems shall be connected to facilities which are outside the bridge scope of work, influence other designs or continue outside the present contract limits.

The interfaces must be identified as early as possible in the design.

Appendix 1 - Contractual Documents Electrical

List of contractual documents for electrical installations and systems.

Index	Title	Document No.	Rev. date
C Preliminary Design	Table of Contents		19.11.04
C-1	Table of Contents	PP1R 001	
	Illustrative Relations	PP1R 002	01.12.02
	Draft safety plan	PP1R004	01.12.02
C-2	Table of Contents	PP2RA0	01.12.02
	Climatic conditions	PP2RA25	
C-3	Technical Relations	PP 2R B0 001	01.12.04
D	Unit prices	No no.	No date
F Engineering	Scope of Works	GCGF01.01	07.10.04
	Codes and Standards	GCGF01.02	15.10.04
	Basis of Design and Expected Performance Levels	GCGF04.01	27.10.04
	Planning	GCGF05.02	10.06.04
	Development of design, requirements and guidelines	GCGF05.03	22.10.04
	System Context	No no.	
	Management & control system	GCGF06.01	12.10.04
G Construction	General	GCGG01.01	13.07.04
	Quality of Materials	GCGG01.02	13.07.04
	Requirements for navigation	GCGG01.03	18.07.04
	Electrical, mechanical and special works (installations)	GCGG03.05	15.07.04

Appendix 2 - Standards

TECHNICAL NORMS AND APPLICABLE LAWS

The main applicable Laws and Technical Norms for the design of the M&E installations are:

- DPR n. 547/55 Norme per la prevenzione degli infortuni sul lavoro
- (DPR n. 459/96 e succ. mod.) .direttive 98/37/CEE nota come "Direttiva Macchine"
- Legge n. 46 , 05/03/1990 "Norme per la sicurezza degli impianti"
- DPR n. 447/91….Legge n. 46 , 05-03-1990 Norme per la sicurezza degli impianti
- Legge n. 615 , 13/07/1966 Provvedimenti contro l'inquinamento atmosferico
- Legge n. 10 , 09/01/1991 Norme in materia di uso razionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili di energia
- Direttiva 06/95/CEE del 12-12-2006 "Riguardante la marcatura CE del materiale elettrico"
- D.Lgs. n. 626 25/11/1996 "Attuazione della direttiva 93/68/CEE (che notifica la direttiva 73/23/CEE) in materia di marcatura CE del materiale elettrico destinato all'essere utilizzato entro taluni limiti di tensione"
- D.Lgs. n. 277 del 31/07/1997 "Modificazioni del decreto legislativo 25 novembre 1996, n. 626 recante attuazione della direttiva 93/68/CEE in materia di marcatura CE del materiale elettrico destinato ad essere utilizzato entro taluni limiti di tensione"

- UNI EN 40 " Pali per illuminazione pubblica"
- UNI 10380 "Illuminotecnica. Illuminazione di interni con luce artificiale"
- UNI 1838 "Applicazione dell'illuminotecnica - Illuminazione di emergenza "
- UNI 10819 "Luce e illuminazione - Impianti di illuminazione esterna - Requisiti per la limitazione della dispersione verso l'alto del flusso luminoso"
- UNI 10439 "Requisiti illuminotecnici delle strade con traffico motorizzato"

Upon approval by the Owner, other Technical Norms and Standards which are more restrictive and recognized by an international authority committee can be used. Furthermore, these norms and standards must be independent from a specific supplier or manufacturer standard.

In the case that the National Laws are more restrictive than the Technical Norms or the ones suggested by the General Contractor, the National Standards shall prevail.

In general, in case of conflicts, the most restrictive Standards or Laws shall be applied.

The General Contractor shall submit within 20 days from the beginning of the designing a detailed list of the Norms and Standards intended to be used for the Design, Manufacturing and testing of the materials and equipment.

Appendix 3 - Design Life

All materials and equipment shall be designed for long life with a minimum of maintenance.

Routine maintenance shall, as far as possible, not require the services of highly skilled personnel.

The required minimum design lives of individual items of equipment covered by this Design Criteria are as follows:

Electrical Power Supply		
7.2 & 24 kV HV on bridge Substation shelter	30 years	
7.2 & 24 kV HV Switchgear	30 years	
7.2 & 24 kV HV Transformers	30 years	
7.2 & 24 kV HV open air cabling	30 years	
7.2 & 24 kV HV underground cabling	50 years	
Instrumentation	15 years	
Electrical low voltage equipments (switchboards, control panels)	25 years	
Electrical low voltage cabling	25 years	
Road lighting luminaire	15 years	
Navigation lighting	10 years	
LED lamps for road lighting	12 years	
LED lamps for navigation lighting	12 years	
LED lamps for interior lighting	12 years	
Metal halogen lamps for illumination of bridge cables	2 years	
Socket outlets	30 years	
Ups Systems	20 years	
Batteries	5 years	
Emergency Stand by Generators	25 years	
External parts of the lightning protection system	25 years	
Earthing and bonding system	30 years	
Earthing plates in concrete surface	100 years	
Earthing bars on the deck	100 years	
Cable ladder and trays	40 years	
Flexible canduits	40 years	
Control and communication Systems		
Fire detection systems	20 years	
CCTV systems	15 years	
Access control system	15 years	
Emergency telephone System	15 years	
Structural Health Monitoring Systems	25 years	

VMS and VS system	15 years	
Weather monitoring system	10 years	
Fibre Optic Cable & Accessories	25 years	
Fibre Optic transmission system	15 years	
Copper transmission Cable & Accessories	25 years	
Multiplex equipments	15 years	
Radio System.	15 years	
Antennas	15 years	
PABX Equipments	15 years	
Equipments Management Systems	15 years	
Telemetry Systems	15 years	
SCADA and Server Computers	5 years	
Mechanical.		
Block valves	25 years	
Check valves	25 years	
Drain valves	25 years	
Pressure relief valves	25 years	
Orifice plate	10 years	
Ductile Iron Pipe & Fittings	45 years	
PVC & HDPE Drainage pipe	40 years	
Water Fire Fighting networks.	20 years	
Plumbing network and equipment in building	25 years	
Flange adaptors	25 years	
Flexible couplings	25 years	
Air supply & Vent Pipe	25 years	
Booster pumps system	15 years	
Dewatering pumps	12 years	
Desalinisation water plant	15 years	
Sewage treatment plant	25 years	
Oil separator	25 years	
HVAC central Unit	15 years	
Air distribution system	25 years	
Fuel storage tank	20 years	
Towers	15 years	
Road lighting poles	15 years	
Gantry for VMS & VS	20 years	
Access ladders & Platform	20 years	
Gate and barriers	15 years	
Under bridge motorised maintenance Platform	15 years	
Cable trays and cable supports	15 years	